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# Water Resources Research Center Annual Technical Report FY 2009

New Hampshire Water Resources Research Center (NH WRRC)

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**Water Resources Research Center  
Annual Technical Report  
FY 2009**

# Introduction

The New Hampshire Water Resources Research Center (NH WRRC), located on the campus of the University of New Hampshire (UNH), is an institute that serves as a focal point for research and information on water issues in the state. The NH WRRC actually predates the Federal program. In the late 1950s Professor Gordon Byers (now retired) began a Water Center at UNH. This Center was incorporated into the Federal program in 1965 as one of the original 14 state institutes established under the Water Resource Research Act of 1964. The NH WRRC is currently directed by Dr. William McDowell with administrative and technical assistance from Associate Director Ms. Michelle Daley and Mr. Jody Potter. The NH WRRC is a standalone organization, in that it is not directly affiliated with any other administrative unit at UNH, and it reports to the Dean of the College of Life Sciences and Agriculture (COLSA). The NH WRRC has no dedicated laboratory or research space, and instead relies on space allocated for the research activities of the WRRC director by COLSA. The NH WRRC does have administrative space on campus, which houses the Associate Director, WRRC files, and short-term visiting staff and graduate students. The WRRC website ([www.wrrc.unh.edu](http://www.wrrc.unh.edu)) serves as a focal point for information dissemination and includes all NH WRRC publications and results from past research, as well as links to other sites of interest to NH citizens and researchers.

## Research Program Introduction

The NH WRRC supported four research projects with its 2009 104b funding:

1. Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds
2. Water Quality Change-Effects of Development in Selected Watersheds
3. Urbanization Impacts on NH Streamwater Thermal Loading
4. A pilot study of septic impacts on water quality using Boron concentrations and isotopes as a source tracer

The Water Quality Analysis Lab (WQAL) is affiliated with the NH WRRC and facilitates water resources research through technical assistance and sample analysis. The WQAL was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH WRRC and housed in James Hall. The mission of the Water Quality Analysis Laboratory is to provide high-quality, reasonably priced analyses in support of research projects conducted by scientists and students from throughout the University, state, and nation. Past clients have included numerous research groups on the UNH campus, Federal agencies, scientists from other universities, and private firms. Many thousands of analyses are conducted each year.

## Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

### Basic Information

<b>Title:</b>	Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds
<b>Project Number:</b>	2003NH21B
<b>Start Date:</b>	3/1/2003
<b>End Date:</b>	2/28/2011
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	NH01
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Non Point Pollution, Surface Water, Nutrients
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	William H H. McDowell

### Publications

1. Buyofsky, Lauren A., 2006, Relationships between groundwater quality and landscape characteristics in the Lamprey River watershed, "MS Dissertation", Department of Natural Resources, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 176 pages.
2. Daley, M.L., J.D. Potter and W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: impacts of road salt and hydrologic variability. *Journal of the North American Benthological Society* 28(4):929-940.
3. DiFranco, E. 2009. Spatial and temporal trends of dissolved nitrous oxide in the Lamprey River watershed and controls on the end-products of denitrification. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 108 pages.
4. Daley, M.L. and W.H. McDowell. In Preparation. Nitrogen saturation in highly retentive coastal urbanizing watersheds. *Ecosystems*.
5. Daley, M.L. 2009. Nitrogen Sources and Retention within the Lamprey River Watershed and Implications for Management. State of the Estuaries Conference. Somersworth, NH. October 2009.
6. Daley, M.L. 2009. Water Quality of Private Wells in Suburban NH and Impacts of Land Use. Northeast Private Well Symposium. Portland, ME. November, 2009.
7. Daley, M.L. 2009. Spatial and Temporal variability in nitrogen concentrations, export and retention in the Lamprey River watershed. Joint NH Water and Watershed Conference. Concord, NH. November, 2009.
8. Daley, M.L. and W.H. McDowell. 2009. Nitrogen Saturation in Highly Retentive Watersheds? American Geophysical Union Fall Conference, San Francisco, CA. December, 2009.

## **Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds**

### **Statement of Critical Regional or State Water Problem**

New Hampshire's surface waters are a very valuable resource, contributing to the state's economic base through recreation (fishing, boating, and swimming), tourism and real estate values. Many rivers and lakes also serve as local water supplies. New Hampshire currently leads all New England states in the rate of development and redevelopment (2000 Census). The long-term impacts of population growth and the associated changes in land use to New Hampshire's surface waters are uncertain. Of particular concern are the impacts of non-point source pollution to the state's surface waters (e.g. septic systems, urban runoff, stormwater, road salt application, deforestation and wetland conversion). Long-term datasets that include year-to-year variability in precipitation, weather patterns and other factors will allow adequate documentation of the cumulative effects of land use change and quantification of the effectiveness of watershed management programs.

### **Statement of Results or Benefits**

The proposed project will provide detailed, high-quality, long-term datasets which will allow for a better understanding of the impacts of land use change and development on surface water quality. This could occur through the development, testing and refinement of predictive models, accurately assessing the impacts of watershed management practices, and potentially early warning of dramatic changes to surface water quality in the region resulting from rapid development.

### **Objectives of the Project**

This project allows for the continued collection of long-term water quality data in New Hampshire. It will use UNH staff, students and volunteers from local communities to collect samples from the College Brook watershed (Durham, NH), the Lamprey River watershed, and the Ossipee River watershed.

Water samples are collected from the following sub-projects.

The **College Brook** watershed, which is dominated by the University of New Hampshire, receives a variety of non-point pollution from several different land uses. Dissolved organic carbon (DOC), total dissolved nitrogen (TDN), nitrate ( $\text{NO}_3\text{-N}$ ), ammonium ( $\text{NH}_4\text{-N}$ ), dissolved organic nitrogen (DON), orthophosphate ( $\text{PO}_4\text{-P}$ ), chloride ( $\text{Cl}^-$ ), sulfate ( $\text{SO}_4\text{-S}$ ), sodium ( $\text{Na}^+$ ), potassium ( $\text{K}^+$ ), magnesium ( $\text{Mg}^{+2}$ ), calcium ( $\text{Ca}^{+2}$ ), and silica ( $\text{SiO}_2$ ), pH and conductivity are measured to assess water quality. Samples from 3 sites are collected monthly throughout the year. Sampling of College Brook began in 1991. Sample collection is done by UNH staff and/or students and samples are analyzed in the Water Quality Analysis Lab at UNH.

The **Lamprey River** has been sampled weekly and during major runoff events since October 1999. Samples are analyzed for DOC, TDN, NO<sub>3</sub>-N, NH<sub>4</sub>-N, DON, and PO<sub>4</sub>-P. Additionally, samples collected since October 2002 are also analyzed for total suspended sediment (TSS), particulate carbon (PC), particulate nitrogen (PN), dissolved inorganic carbon (DIC), Cl<sup>-</sup>, SO<sub>4</sub>-S, Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>+2</sup>, Ca<sup>+2</sup>, SiO<sub>2</sub>, pH, conductivity, dissolved oxygen (DO) and temperature. In January of 2004, we began routine sampling of additional Lamprey stream sites for dissolved organic matter (DOM) nitrogen, phosphorus and other parameters. During 2004 all stream sites were sampled on a weekly basis, in January 2005, the frequency of stream sampling was curtailed to monthly (instead of weekly) for 10+ sampling sites. Three stream sites (the Lamprey River, the North River and Wednesday Hill Brook) remained at a weekly and major storm event sampling frequency.

From November 2003 to January 2005, bulk precipitation samples were collected on a weekly basis at numerous locations throughout the basin for analysis of nitrogen, phosphorus, DOM, major cations and anions and silica. Precipitation data from this time period indicated that rain chemistry within the Lamprey watershed does not vary spatially. Therefore since January 2005, we have collected wet-only precipitation samples from one collector in the watershed on an event to weekly basis. Several volunteers have been monitoring precipitation volume throughout the basin since October 2003 and will continue to do so as precipitation amount is spatially variable. All stream water and precipitation samples are collected by UNH staff and/or students and analyzed by the Water Quality Analysis Lab at UNH.

#### **Groundwater Chemistry and nutrient dynamics.**

Monthly ground water well samples have been collected from the James Farm and L1 well fields in Lee, New Hampshire within the Lamprey River watershed. James Farm monthly samples were collected from January to September of 1995 and from July 2004 through December 2006. L1 monthly samples were collected from July 2004 through December 2006. Quarterly groundwater samples have been collected since January 2007 at both locations. All groundwater samples are collected by UNH staff and/or students and analyzed by the Water Quality Analysis Lab at UNH.

#### **Ossipee Watershed**

Volunteers of the Green Mountain Conservation Group sample streams within the Ossipee watershed of New Hampshire. Samples are collected every 2 weeks from May to November, and monthly during the winter months. Water chemistry (DOC, TDN, NO<sub>3</sub>-N, NH<sub>4</sub>-N, DON, PO<sub>4</sub>-P, Cl<sup>-</sup>, SO<sub>4</sub>-S, Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>+2</sup>, Ca<sup>+2</sup>, SiO<sub>2</sub>) is measured on selected samples by the NH WRRC and WQAL. WRRC staff will assist in data interpretation.

#### **Methods, Procedures and Facilities**

Samples are collected at intervals described above. Samples are filtered in the field using pre-combusted glass fiber filters (0.7 µm pore size), and frozen until analysis. All samples are analyzed in the Water Quality Analysis Lab of the WRRC on the campus of UNH, Durham, NH.

The Water Quality Analysis Laboratory (WQAL) was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH Water Resources Research Center and housed in James Hall. Dr. William McDowell is the Laboratory Director, Jeffrey Merriam was the Laboratory Manager until January 2010 and now Jody Potter manages the WQAL. Together, they have over 40 years of experience in water quality analysis, and have numerous publications in the fields of water quality, biogeochemistry, and aquatic ecology.

Methods for analyses include ion chromatography ( $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$  and  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{+2}$ ,  $\text{Ca}^{+2}$ ), discrete colorimetric analysis ( $\text{NH}_4$ ,  $\text{PO}_4$ ,  $\text{NO}_3/\text{NO}_2$ ), and High Temperature Oxidation (DOC, TDN). All methods are widely accepted techniques for analysis of each analyte.

## **Principal Findings and Significance**

### **College Brook**

Previous work on College Brook in the early 1990's (McDowell unpublished) shows that the UNH campus had a severe impact on water quality and was negatively affecting stream biota and the integrity of downstream ecosystems. By any yardstick, campus operations could not be considered sustainable. There was clear evidence that the UNH incinerator was causing excessive organic matter loading, resulting in high biochemical oxygen demand (BOD) and low dissolved oxygen (DO) in stream water. Since the incinerator has been closed, BOD and DO are no longer at levels detrimental to in-stream biota. Our monthly sampling regime was scaled back beginning October 2006 to the 3 stations that have historically shown the greatest changes, and we eliminated the BOD and TSS measurements (both which change little over the reach since the incinerator was closed). The most downstream sampling location is now closer to where the stream empties into the Oyster River in an effort to better quantify inputs to the Great Bay estuary. We also added a 4<sup>th</sup> site on Pettee Brook in Durham, NH in May 2008 that was previously sampled. Analyses of samples collected through 2008 have been completed and we are in the process of analyzing 2009 samples and updating our website: [http://www.wrrc.unh.edu/current\\_research/collegebrook/collegebrookhome.htm](http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm).

Dissolved Oxygen (DO) in the brook is lower at the upstream stations. This difference is presumably due to hydrologic properties of the upstream sampling location which resembles a wetland (i.e. slow flow, higher organic matter and dissolved organic carbon). DO increases downstream as flow becomes faster and re-aeration higher.

Data from 2000-2008 indicate that the stream is strongly impacted by road salt at its origin, which is essentially a road-side ditch leading to a wetland area. Average Sodium and Chloride concentrations, as well as specific conductance, appear to have remained reasonably constant since 2001, but are much higher than in 1991 (Daley et al. 2009). Concentrations are highest at the upstream stations and tend to decline downstream as the stream flows through the campus athletic fields and then increase as the stream passes through the heart of campus and downtown Durham.



Since Great Bay and Little Bay are “impaired” by elevated nitrogen, nitrogen (especially in the form of nitrate) exported from College Brook and into Little Bay is cause for concern. College Brook becomes more aerated as it moves downstream and ammonium decreases as nitrate increases indicating that nitrification is occurring in the stream channel, however the mass of each and an increase in total nitrogen indicates that there are additional sources of nitrate to the stream. This is possibly from fertilization of the athletic fields and/or storm water runoff. There also appears to be a slight, but insignificant, increase in nitrate over time. This will need to be closely monitored as algal blooms and loss of Eelgrass have become a concern in Great Bay and Little Bay.

### **Lamprey River Watershed**

The Lamprey River watershed is a rural watershed located in southeastern NH and is under large development pressure as the greater area experiences the highest population growth in the state. The Lamprey River Hydrologic Observatory (LRHO) is a name given to the entire Lamprey River basin as it serves as a platform to study the hydrology and biogeochemistry of a suburban basin and is therefore used by the UNH community as a focal point for student and faculty research, teaching and outreach. Our goal for the long-term Lamprey water quality monitoring program is to document changes in water quality as the Lamprey watershed becomes increasingly more developed and to understand the controls on N transformations and losses. We have continued to sample the Lamprey River at the USGS gauging station in Durham, NH (referred to as “L73”), the North River at the former USGS gauging station in Epping, NH (N27) and a small tributary to the Lamprey River in Lee, NH (W01) on a weekly basis and 13 other stations throughout the watershed on a monthly basis. Analyses of samples collected through 2009 have been completed and we have updated the LRHO website (<http://www.wrrc.unh.edu/lrho/index.htm>). The USGS discontinued the operation of the North River gauging station in October 2006 and since then we have been recording weekly stage height and calculating flow based on the USGS rating curve. We are able to record stream flow at W01 using an electronic distance meter in combination with a rating curve that we have developed for this site. We have also developed a stream flow model for W01 where daily discharge can be estimated from meteorological measurements (such as precipitation and temperature) and this model is useful for estimating historic flows. We continue to collect precipitation at Thompson Farm (UNH property located in Durham, NH) to document nitrogen inputs to the basin and this data is posted on the AIRMAP website (<http://airmap.unh.edu/>).

Results of stream chemistry to date show a significant increase in nitrate concentrations over time (Water Years (WY) 2000-2009) in the Lamprey River (Figure 1) and no change in nitrate concentrations in the North River or Wednesday Hill Brook over a shorter time period (2004-2009). We have shown previously that stream water nitrate is related to watershed population density (Daley 2002) and since suburbanization continues to occur throughout the greater Lamprey River watershed, population growth is likely responsible for the increase in stream water nitrate. Wednesday Hill Brook watershed is near its development capacity, unless the Town of Lee, NH changes its zoning regulations, and the lack of increase in W01 nitrate may be due to the limited

population growth in this watershed, that this watershed has reached nitrogen saturation or that the relatively short period of data collection is not reflective of long-term trends.

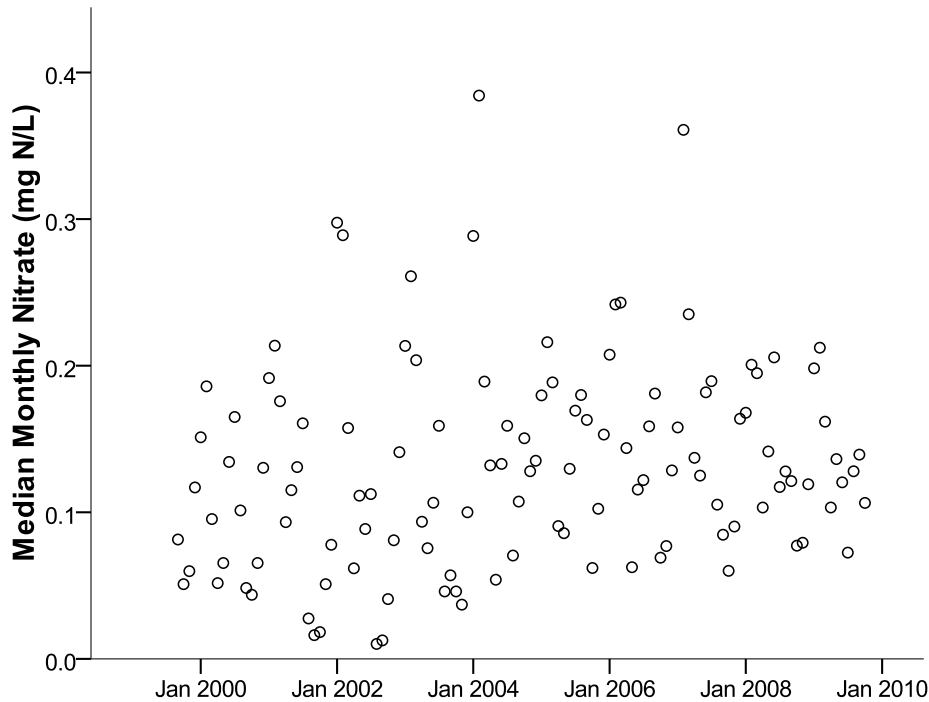


Figure 1. Median monthly nitrate concentrations over time in the Lamprey River at the USGS gauging station in Durham, NH.

When we combine our specific conductance data (2002 – 2009) with data collected by the USGS (1978 - 1999), we see a long-term increase in specific conductance in the Lamprey River (Figure 2). Sodium and chloride concentrations are directly related to specific conductance ( $r^2 = 0.95$ ,  $p < 0.01$  for  $\text{Na}^+$ ;  $r^2 = 0.93$ ,  $p < 0.01$  for  $\text{Cl}^-$ ) and we conclude that this increase in specific conductance indicates a corresponding increase in NaCl. Since  $\text{Na}^+$  and  $\text{Cl}^-$  are strongly correlated with impervious surfaces in southeast NH (Figure 3) and road pavement among southeastern and central NH basins. We conclude that the associated road salt application to these surfaces is responsible for these spatial and temporal changes in streamwater NaCl.

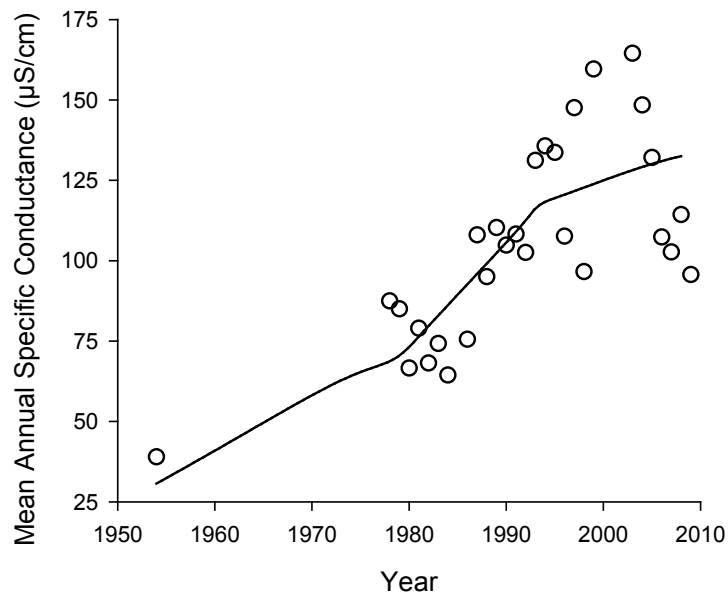


Figure 2. Mean annual specific conductance in the Lamprey River at the USGS gauging station in Durham, NH. (Daley et al. 2009).

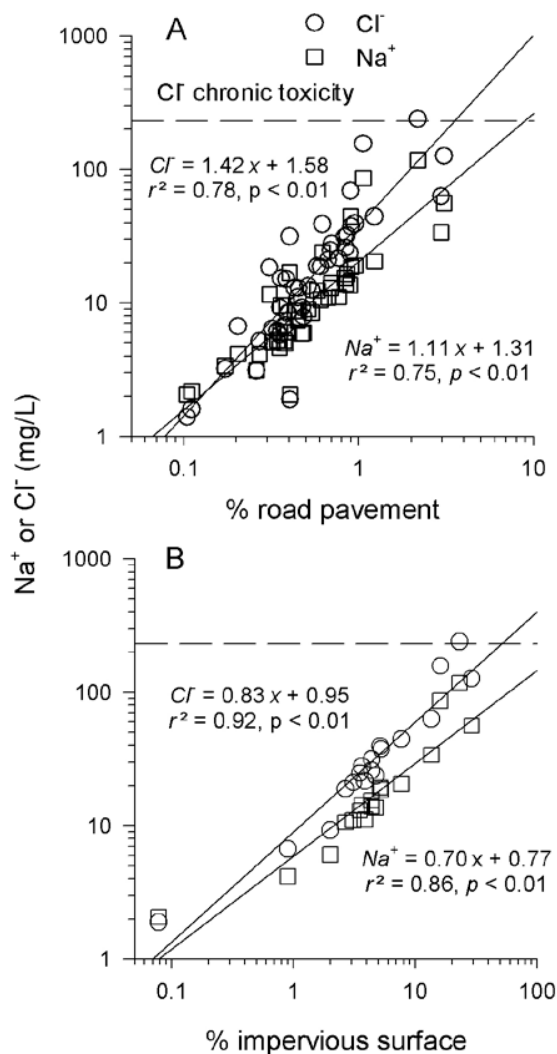


Figure 3. Relationship between both average concentrations of  $\text{Na}^+$  (squares) and  $\text{Cl}^-$  (circles) and a.) % road pavement (College Brook, Lamprey and Ossipee sub-basins) and b.) % impervious surfaces (College Brook and Lamprey sub-basins only) (Daley et al. 2009).

Results of precipitation monitoring show that wet deposition and estimated dry deposition together account for more than half of the N input to the Lamprey watershed and that wet deposition chemistry can be linked to air mass chemistry. DOC and TDN in precipitation are related to biogenic air mass sources,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_3\text{-N}$  and  $\text{SO}_4\text{-S}$  are related to urban/industrial air masses and Na and Cl are weakly related to ocean aerosols.

#### Groundwater Chemistry and Nutrient Dynamics.

James Farm ground water nitrate concentrations have shown conflicting patterns over the past ten years. There has been no change in nitrate concentrations among 4 wells, nitrate has increased in two wells and decreased in one well. L1 ground water nitrate concentrations have remained constant or decreased slightly from 2004-2008 with

the exception of one well (L1A-21) where nitrate increased from <0.2 to 3.0 mg N/L. Decreased concentrations in recent years may reflect dilution by two 100 flood events in 2006 and 2007. James Farm and L1 ground water data demonstrates higher  $\text{NO}_3^-$  concentrations with low dissolved organic carbon (DOC) concentrations as well as low  $\text{NO}_3^-$  concentrations with high DOC concentrations, which suggests possible denitrification influencing ground water  $\text{NO}_3^-$  concentrations.

### **Ossipee Watershed**

Collaboration with the Green Mountain Conservation Group and their sampling of the Ossipee River watershed has continued to be beneficial. Volunteers sampled streams within the watershed every 2 weeks from April through October, and monthly winter sampling occurs at 7 sites, with approximately 340 samples collected from 30 sampling locations. Many presentations were made to planning boards, conservation commissions and other local government groups (see Information Transfer section below). Data have been used to heighten awareness of the impacts of excessive road salting and snow dumping in local streams. The impact of road salting in this central NH watershed is similar to what we see in coastal NH (Figure 3a). Communication with local road agents has led to the remediation in one development where road salting was an issue. Samples collected and data generated from this funding have shown an improvement in water chemistry following reduced salting and snow dumping. Data have also been useful in promoting low impact development techniques and best management practices where new development has been proposed in proximity to rivers and streams within the watershed.

### **Publications:**

Daley, M.L., J.D. Potter and W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: impacts of road salt and hydrologic variability. *Journal of the North American Benthological Society* 28(4):929–940.

Daley, M.L. and W.H. McDowell. *In Preparation*. Nitrogen saturation in highly retentive coastal urbanizing watersheds. *Ecosystems*.

DiFranco, E. 2009. Spatial and temporal trends of dissolved nitrous oxide in the Lamprey River watershed and controls on the end-products of denitrification. M.S. Dissertation, Department of Natural Resources & the Environment, College of Life Science and Agriculture, University of New Hampshire, Durham, NH, 108 pages.

McDowell, W.H., M.L. Daley, B. Sive and R. Talbot. *In Preparation*. Factors controlling atmospheric deposition at a coastal suburban site. *Journal of Geophysical Research (Atmospheres)*. 2010.

### **Conference Proceedings & Abstracts:**

- Daley, M.L. 2009. Nitrogen Sources and Retention within the Lamprey River Watershed and Implications for Management. State of the Estuaries Conference. Somersworth, NH. October 2009.
- Daley, M.L. 2009. Water Quality of Private Wells in Suburban NH and Impacts of Land Use. Northeast Private Well Symposium. Portland, ME. November, 2009.
- Daley, M.L. 2009. Spatial and Temporal variability in nitrogen concentrations, export and retention in the Lamprey River watershed. Joint NH Water and Watershed Conference. Concord, NH. November, 2009.
- Daley, M.L. and W.H. McDowell. 2009. Nitrogen Saturation in Highly Retentive Watersheds? American Geophysical Union Fall Conference, San Francisco, CA. December, 2009.
- McDowell, W.H. 2009. Biogeochemistry of Suburban Basins – Putting People into the Landscape. University of Georgia. Athens, GA. October, 2009.
- McDowell, W.H. 2009. Biogeochemistry of Suburban Basins – Putting People into the Landscape. University of Reading, United Kingdom. November, 2009.

#### **Information Transfer:**

- Daley, M.L. 2009. Current Water Quality Research in the Lamprey River Watershed. Southern New Hampshire Planning Commission Meeting. Manchester, NH. April 2009.
- Daley, M.L. 2009. Current Water Quality Research in the Lamprey River Watershed. Rockingham Planning Commission and Strafford Regional Planning Commission special joint meeting. Exeter, NH. May 2009.
- Daley, M.L. 2009. Water Quality Research in the Lamprey River Watershed: Road Salt and Nitrogen. Lamprey River Outreach Conference: “Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes Sense For Protecting Our Water”. Nottingham, NH. June 2009.
- Daley, M.L. 2009. Current water quality research in the Lamprey River watershed. Lamprey River Advisory Committee. Durham, NH. October 2009.
- Daley, M.L. 2009. Salt Research, Impacts to Surface & Ground Water. Road Salt BMPs for the Ossipee Watershed. Chocorua, NH. November 2009.
- Daley, M.L. 2010. Nitrogen Saturation in the Highly Retentive Lamprey River Watershed? Annual Lamprey River Science Symposium. Durham, NH. January 2010.
- Dunlap, K. 2010. Seasonal Nitrate Dynamics in a New Hampshire Agricultural Stream. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

McDowell, W.H. 2010. Overview of the Lamprey River Hydrologic Observatory Objectives. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

**Presentations made by the Green Mountain Conservation Group staff March 2009 - February 2010.**

March 7<sup>th</sup> Smart About Water Workshop with RCAP @ Tin Mountain  
March 22<sup>nd</sup> Wild & Scenic Environmental Film Festival – WQM booth & info  
March 27<sup>th</sup> Ossipee Aquifer Steering Committee Meeting  
April 2<sup>nd</sup> Drinking Water Tool Kit & NH Water Primer w/ NH DES in Ossipee  
April 11<sup>th</sup> WQM Volunteer Training  
April 13<sup>th</sup> Tamworth Conservation Commission & Planning Board WQM Presentation  
April 17<sup>th</sup> Ossipee Aquifer Steering Committee Meeting  
April 22<sup>nd</sup> WQM Presentation for Calumet Saving the Planet Retreat  
May 7<sup>th</sup> Regional Presentation for WQM with LRPC, Dr. Newton, NH DES & RCAP in Madison  
May 8<sup>th</sup> WQM & Soils Workshop with UNH CE  
June 3<sup>rd</sup> Camp Director Meeting & Presentation  
June 26<sup>th</sup> Ossipee Aquifer Steering Committee Meeting  
July 1, 2, 15, 16 Volunteer Lake Assessment Program & WQ Programs with Camps Cody, Huckins, Robin Hood, Marist & Danforth Bay  
June 30, July 14, 28, Aug. 11 WQ Programs/Ossipee Lake & Tributary testing with Camp Calumet  
July 24 Ossipee Aquifer Steering Committee Meeting  
August 1 Household Hazardous Waste Day WQ Table in Ossipee  
August 12 VLAP & WQM Presentation with NH DES in Ossipee  
August 13 WQ & Shoreline Protection BMPs Workshop in Tamworth  
August 24 VBAP & WQM Volunteer Training  
Sept. 11 Ossipee Aquifer Steering Committee Meeting  
Sept 1-18 VBAP Programs & WQM daily with Ossipee Central School, Tamworth Learning Circles, Sandwich Elementary School & Brett School in Tamworth  
Oct. 22<sup>nd</sup> Ossipee Aquifer Steering Committee Meeting  
Oct 18<sup>th</sup> Lakeview Celebration w/ WQM GIS presentation  
November 5<sup>th</sup> Regional Road Salt Workshop in Chocorua  
November 18<sup>th</sup> Community School Presentation in Tamworth of VBAP & WQ  
January 8<sup>th</sup> Ossipee Aquifer Steering Committee Meeting  
January 24<sup>th</sup> Annual Meeting with WQ presentation in Freedom  
February 5<sup>th</sup> Ossipee Aquifer Steering Committee Meeting

**Number of students supported:**

Four Master's students (Kate Dunlap, Michelle Galvin, Amanda Hope and Emily DiFranco) and four undergraduate hourly employees (Daniella Williams, Valerie Schoepfer, Taylor Langkau and Liz Holden)

# Water Quality Change-Effects of Development in Selected Watersheds

## Basic Information

<b>Title:</b>	Water Quality Change-Effects of Development in Selected Watersheds
<b>Project Number:</b>	2006NH60B
<b>Start Date:</b>	3/1/2006
<b>End Date:</b>	2/28/2011
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	NH01
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Non Point Pollution, Nutrients, Surface Water
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Jeffrey Schloss

## Publications

1. Craycraft, R. and J.A.Schloss, 2009. New Hampshire Lakes Lay Monitoring Program Yearly Report 2008. 28 individual lake reports 18 to 160 pages each. University of New Hampshire Center for Freshwater Biology. Durham, NH.
2. Craycraft, R. and J.A.Schloss, 2009. Newfound Watershed Assessment Project 2007 and 2008. Special report in fulfillment for the NH DES 319 Watershed Assistance Grant. University of New Hampshire Center for Freshwater Biology. Durham, NH. 170 pages (report 83pp, appendices 87pp).
3. Wilderman, Susan E. 2009. Contributions of Groundwater Seepage to the Water and Nutrient Budget of Mendums Pond Barrington, New Hampshire. MS Thesis. University of New Hampshire. Durham, NH. May 2009.



## **Effects of Development on Nutrient Loading: Septic System Influence Status Report: March 1 2009 through February 28 2010**

### Statement of Regional or State Water Problem-

The waters of New Hampshire represent a valuable water resource contributing to the state's economic base through recreation, tourism, and real estate revenues. Some lakes and rivers serve as current or potential water supplies. For most residents (as indicated by boating and fishing registrations, shoreline re-development) our waters help to insure a high quality of life. As documented in the 2000 Census, New Hampshire currently leads all of the New England states in the rate of new development and redevelopment. The long-term consequences of the resulting pressure and demands on the state's precious water resources remain unknown. Of particular concern is the response of our waters to increasing non-point source pollutant loadings due to watershed development and land use activities.

Of all the in-depth watershed nutrient budget measurements and modeling efforts that have been attempted in NH none have included an in depth analysis of septic system influences from newly built and legacy septic systems. The current project expanded on an existing study of septic system hydrology to evaluate the use of emerging contaminant markers such as caffeine and triclosan to assess septic influence on water quality. In addition project work continued to support our long-term monitoring program conducted through differing weather years at both shallow and deep lake sites that offer the potential to cost effectively estimate the lake response to the loadings due to development over time.

### Objectives:

- 1- To initiate analysis of water samples collected at septic tanks, test wells and near shore for a range of septic systems of various ages in a range of suitable and unsuitable soils/slopes.
- 2- The continued collection and analysis of long-term water quality data in selected watersheds.
- 3- The dissemination of the results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.
- 4- To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
- 5- To further document the changing water quality in a variety of watersheds throughout the state in the face of land use changes and best management efforts.
- 6- To determine next steps for further analysis of long-term data sets and GIS spatial data on land cover.
- 7- To assist state agencies and communities in setting Total Phosphorous concentration targets as part of their lake watershed management plans.

### Methods:

The septic study was primarily based at the Squam Lakes where we have already conducted an extensive water and nutrient budget study and have compiled a complete GIS analysis system that includes septic system locations and specifications. The Squam

Lakes (Squam and Little Squam Lake) benefit from the absence of point sources of pollution like wastewater treatment facilities, industrial facilities or large agricultural operations in close proximity to the shore; however, the role of non-point sources of pollution continues to be an issue. In 2001, Schloss et al. conducted a preliminary survey of septic systems around the Squam Lakes. They found that certain basins were at elevated risk of pollution by septic systems where age of system/design, soil characteristics and slopes were unfavorable to septic waste treatment. This study collected environmental samples from five of the basins found to be at high risk for pollution, one basin at moderate risk, and one basin found to be at low risk of pollution by shore side property septic systems (Figure 1). Shallow water samples were collected using a Van Dorn sampler at 0.5 meters or less. Samples were analyzed for Total Phosphorous in the UNH Center for Freshwater Biology Analytical Laboratory. The emerging contaminants caffeine and triclosan were analyzed through ELISA procedures using very high sensitivity test kits from Abraxis Analytical. Samples from some of these same sites as well as additional river sites bracketing sewage treatment facilities were also analyzed for specific anions/cations, boron, boron isotopes, and, using a modified HPLC/MS procedure: acetaminophen (a common analgesic), caffeine, carbamazepine (an antiepileptic, mood stabilizer) and trimethoprim (an antibiotic) as part of a companion study funded through the NH WRRC and will be reported upon elsewhere.

Emphasis on Lakes Lay Monitoring Program efforts was on expanding shallow water monitoring sampling to try to detect septic leachate influences. Lake and stream monitoring through the LLMP generally involved a minimum of monthly sampling starting at spring runoff through to lake stratification and weekly to bi-weekly sampling through to fall mixis. Water clarity, chlorophyll a, acid neutralizing capacity, dissolved organic color, dissolved oxygen and nutrients (total N, total P and nitrate) were the default suite of parameters measured for lakes while nutrients, turbidity, dissolved organic color and flow were the parameters of choice for the lake tributary work. On occasion, student field teams traveled to join the volunteer monitors to perform quality assurance checks and do more in-depth analysis and lake profiling.

#### Major Findings and Significance:

As of February 28, 2010 samples were still being processed and analyzed. In addition we will be doing additional sampling this summer to confirm positive results and expand our sampling base. We expect to have the full project completed before February 2011. Preliminary results received March 2010 indicate significant differences between control and targeted samples.

#### Publications, Presentations, Awards:

##### Reports:

Craycraft, R. and J.A.Schloss 2009. New Hampshire Lakes Lay Monitoring Program Yearly Report 2008. 28 individual lake reports 18 to 160 pages each. UNH Center for Freshwater Biology. University of NH. Durham, NH.(see appendix for report names and pages).

Craycraft, R. and J.A.Schloss 2009. Newfound Watershed Assessment Project 2007 and 2008. Special report in fulfillment for the NH DES 319 Watershed Assistance Grant. UNH Center for Freshwater Biology. University of NH. Durham, NH. 170pages (report 83pp, appendices 87pp)

Peer Reviewed Reports:

Craycraft, R. and J.A.Schloss 2009. Newfound Lake Watershed Assessment Project Quality Assurance Project Plan Amendment for 2010 Sampling Program. UNH Center for Freshwater Biology. University of NH. Durham, NH. 28pp.

Presentations:

March 24, 2009- "Summary of the Mendums Pond Watershed Study". J.A. Schloss, S Wilderman, R. Craycraft (invited) to the Barrington Selectmen, Planning Board, Conservation Commission and general public. Barrington NH.

April 13, 2009 Landscaping at the Water's Edge: An Ecological Approach. J.A. Schloss Full day workshop (invited) in Portage IN for US EPA Region 5.

April 14, 2009. "On the Edge: Enhancing Ecological Integrity of Shorelines" JA Schloss, M. Bickendorfer, P. Goggin. (invited) full day pre-conference workshop for Enhancing State Lake Management Programs Conference. Chicago IL.

June 26, 2009. "New High-Tech Tools for Lake Management" J.A. Schloss (invited). NH Lakes 17<sup>th</sup> Lakes Congress, NH Lakes Association. Colby Sawyer College, New London, NH.

October 31, 2009 "Landscaping at the Waters Edge: An Ecological Approach" J. Schloss (invited) half day workshop for the North American Lake Management Society International Symposium, Hartford CT.

November 24, 2009- "Nutrient Budgets for NH Lakes-implications for TMDL models" J.A.Schloss, NH Water Resources Research Center, UNH Natural Resources Dept., NH USGS –Water Resources Brown bag seminar series. Durham NH.

Publications from WRRC supported work completed in previous years and not reported previously:

Wilderman, Susan E. 2009. Contributions of Groundwater Seepage to the Water and Nutrient Budget of Mendums Pond Barrington, New Hampshire. Masters Thesis. University of New Hampshire. Durham, NH. May 2009.

Outreach Activities:

May 19, 2009. J.Schloss. Landscaping at the Waters Edge: Reigning in Runoff for the Town of Dover and Dover open lands committee (televised).

July 10, 2009. J. Schloss, R. Craycraft, J Haney, A. Baker. NH LLMP 30 Year Anniversary Meeting/Symposium. Durham, NH.

September 23, 2009. J. Schloss. "Farm Field Forest Buffers for River Water Quality Protection". Walpole NH. In conjunction with UNH Cooperative Extension and US Fish and Wildlife Service.

September 25, 2009. J.Schloss. Invited presentation and field tour for the NH Lakes Management Advisory Committee: "Over 30 years of Research on Squam: Lessons learned". Squam Lakes Association, Holderness NH.

On going monthly meetings with Lake Winnepesaukee Watershed Project Steering Committee concerning P modeling for local decision-makers to set target lake P concentrations (Center Harbor, Guilford and Laconia).

Number of students supported:

Directly: (partial wage/salary funding)

Graduate:

Jeff Schloss	PhD	Natural Resources and Earth Systems Science
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Undergraduate:

Lejla Kadic	BS	Biology (Premed)
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Gabrielle Hodgman	BS	Biology (General)
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Indirectly (supply support, LLMP project)

Undergraduate:

Taylor Salas	BS	Marine Biology	University of Vermont
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Emma Leslie	BS	Zoology	
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Jesica Waller	BS	Marine Biology	
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Jessy Klotzer	BS	Zoology (PreVet)/Biochemistry	
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# Grant No. 06HQGR0143 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.

## Basic Information

<b>Title:</b>	Grant No. 06HQGR0143 Determining the Effectiveness of the Clean Air Act and Amendments for the Recovery of Surface Waters in the Northeastern U.S.
<b>Project Number:</b>	2006NH86S
<b>Start Date:</b>	3/6/2006
<b>End Date:</b>	2/28/2011
<b>Funding Source:</b>	Supplemental
<b>Congressional District:</b>	1
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Steve Kahl, William H H. McDowell

## Publications

1. Hunt, K., J.S. Kahl, J. Rubin, and D. Mageean, 2007. Assessing the science-based needs of stakeholders; a case study on acid rain research and policy. *Journal of Contemporary Water Research and Education*, 136: 68-79.
2. Rosfjord, C., K. Webster, J.S. Kahl, S.A. Norton, I. Fernandez, and A. Herlihy, 2007. Anthropogenically-driven changes in chloride complicate interpretation of base cation trends in lakes recovering from acidic deposition. *Environ Sci Technol*, 41:7688 -7693.
3. Baumann, A.J. and J.S. Kahl, 2007. Chemical trends in Maine High Elevation Lakes. *LakeLine* 27:30-34.
4. Rosfjord, C., J.S. Kahl, K. Webster, S. Nelson, I. Fernandez, L. Rustad, and R. Stemberger, 2006. Acidic deposition-relevant changes in lake chemistry in the EPA Eastern Lake Survey, 1984-2004. Final report to USDA NSRC, Durham, NH. 69 p.
5. Nelson, S.J., W.H. Halteman, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, 2010. Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting, and chemical co-variates. *Environmental Science and Technology*, in review.

## Annual Report to

USGS WRD WRRI, Reston, VA  
US EPA, CAMD, Washington DC  
and US EPA, ORD, Corvallis OR

April, 2010

### *Determining the effectiveness of the Clean Air Act and Amendments on the recovery of surface waters in the northeastern US*


IAG 06HQGR0143


Principal Investigators: *Steve Kahl*<sup>1</sup>, *Bill McDowell*<sup>1</sup>, *Sarah Nelson*<sup>2</sup>, and *Katherine Webster*<sup>3</sup>  
<sup>1</sup>Univ. of New Hampshire, <sup>2</sup>Univ. of Maine, <sup>3</sup>Michigan State Univ.


**Overview of activities during 2009.** A schematic summary of progress on the project plan is provided below and discussed on the following pages. We are concluding the fourth year of this five year project that supports the continuing needs of EPA for meeting the Congressional mandate for the agency to assess the effectiveness of the Clean Air Act Amendments of 1990. Field work and data assessment are on schedule, and the supplemental zooplankton component is well underway.


The lead organization for the project is now the University of New Hampshire. The 2009 transition from PSU to UNH was successful both fiscally and logistically. Field and laboratory assistance continues from the University of Maine.

	2006			2007				2008				2009				2010				2011
<i>Project Activity</i>	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
project period																				
funding received																				
RLTM outlets																				
RLTM drainage lakes																				
RLTM seepage lakes																				
original LTM lakes																				
HELM subset																				
BBWM - EB																				
TIME New England																				
TIME Adirondacks																				
sample analyses																				
zooplankton analyses																				
annual report																				
annual data report																				

 = project plan

 = in progress

 = completed

 = cancelled (weather)

## Project background

Objectives. This proposed research is part of the EPA program to collect long-term data on the trends and patterns of response in surface waters sensitive to acidic deposition. The goals and methods are hierarchical from intensive site-specific to regional statistical populations. The objectives are to:

- 1) document the changes and patterns in aquatic chemistry for defined sub-populations and sites that are known to be susceptible to acidification or recovery;
- 2) evaluate linkages in changes in surface waters, if any, to changes in deposition that are related to regulatory goals;
- 3) characterize the effectiveness of the Clean Air Act Amendments in meeting goals of reducing acidification of surface waters and improving biologically-relevant chemistry in the northeastern US; and
- 4) provide information for assessment of the need for future reductions in atmospheric deposition based on the rate of recovery (or not) of the systems under study.

We continue to explore changes in biological condition using zooplankton collected in 2004 under separate funding from 145 ELS-II lakes in the northeast, as part of our 20<sup>th</sup> anniversary re-analysis of the Eastern Lake Survey (see Rosfjord *et al.*, 2007). This re-sampling included total and methyl mercury analyses for lake water, GIS analyses of lake context, and creation of an integrated GIS-chemistry database for the 1986 ELS-II lakes and 2004 re-sampling data.

Approach. The schedule of tasks ranges from weekly to annual, continuing data records that now range from 16 to 25 years. We evaluate chemistry on a weekly basis year-round at the small watershed-scale at BBWM, weekly during the spring melt period at LTM lake outlets when seasonal conditions warrant, quarterly in LTM, and annually during the historical index period for the HELM and TIME lakes. These project components provide a *statistical framework* for inferring regional chemical patterns using TIME and LTM (and ELS-II under separate funding). The *long-term records* of LTM, HELM and BBWM provide information on seasonal and annual variability, and thus provide a seasonal context for the annual surveys.

Expected Results. This information is fundamental for EPA to meet the Congressional mandate for reporting on the effectiveness of the Clean Air Act Amendments (CAAA). The combination of site-specific data within the regional context will provide for an effective assessment of the effects of declining pollutant emissions on SO<sub>4</sub> concentrations, base cation depletion, and changes in N-saturation or DOC contributions to acid-base status. The results are also central to the decisions on additional emission reductions that may be needed to produce recovery.

Name	Class	Town (Gazmap)	Area (ha.)	Depth (m)	Elev (m)
<i>Regular RLTM sites:</i>					
Abol Pond	thick till	T 2 R 9 (50)	36	10	181
Bean Pond	med. till, high DOC	Pleas Ridge (30)	12	9	381
Bracey Pond	GW seepage	T 34 MD (34)	8	9	117
Crystal Pond	perched/seepage	T 40 MD (34)	10	9	113
Duck Pond	perched/seepage	T 22 MD (24)	2	3	82
Jellison Pond	med. till, low DOC	Amherst (24)	18	17	123
Newbert Pond	thin till, high DOC	Appleton (14)	13	4	89
Mud Pond	thin till, low DOC	T 10 SD (24)	1	15	104
Partridge Pond	thin till, low DOC	Amherst (24)	9	7	175
Salmon Pond	med. till, low DOC	T 10 SD (25)	4	10	94
Second Pond	thin till, high DOC	Dedham (23)	27	13	126
Wiley Pond	med. till, high DOC	Patten (51)	11	6	235
<i>LTM Supplemental Lakes:</i>					
Anderson Pond	thin till, low DOC	T 10 SD (25)	5	6	66
Little Long Pond	thin till, low DOC	T 10 SD (25)	24	25	75
Tilden Pond	thin till, low DOC	T 10 SD (25)	15	9	72

### LTM/TIME annual field schedule

LTM-Maine	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1 Bean		X			X		w/ HELM	
2 Partridge		X		X				X
3 Jellison Hill		X		X				X
4 Crystal		X		X			X	
5 Duck		X		X			X	
6 Bracey		X		X			X	
7 Newbert	X			X				X
8 Wiley		X			X		X	
9 Abol		X			X		X	
10 Mud		X		X				X
11 Salmon		X		X				X
12 Tunk outlet		X		X				X
13 Second		X		X				X
14 Little Long								X
15 Tilden								
16 Anderson								
<b>TIME-Maine</b>								
1 Round Pond		w/ TIME NH			X			
2 Mountain Pd		fly with HELM					fly w/ HELM	
3 Bog Pd Hartland		w/ Bean in spring and summer			X			
4 East Branch Lake		[Penobscot Nation sample]			X			
TIME NH					X	X	X	
TIME New Engl						X	X	
TIME NY						X	X	X
HELM							X	X

Spring weekly drainage lake samples: weather and snowcover dependent



## **Project Status: Water Chemistry**

**Field sampling.** All project field objectives in 2009 were accomplished as planned with the exception of the spring drainage lake samples. Maine experienced an extremely wet spring making spring sampling logistically difficult and potentially unsafe for field crews.

**Analytical.** Analyses are complete for all samples collected through 2009, except for total aluminum. Aluminum samples are currently being analyzed by ICP and the USDA Forest Service Region 1 laboratory in Durham, NH. Analysis delays are the result of laboratory remodeling and instrument repair. We anticipate completion of the Al analyses by the end of April 2009.

Samples from East Bear Brook at BBWM, which are collected on a regular basis year around, continue to be analyzed in a contract laboratory at UMaine.

**Data reporting.** All data collected through 2008 have been delivered to EPA. The next delivery of data to EPA is expected in spring 2010, after evaluation of inter-laboratory comparisons and regular QA analyses by UNH and UMaine. Substantial unexpected (and unbudgeted) effort in 2009 went into moving our long-term database from mainframe SAS at UMaine to PC SAS, caused by the discontinuation of the mainframe at UMaine.

**Presentation of findings.** Several publications and presentations have resulted from this project since the final report for the previous LTM/TIME grant, listed at the end of this report. We recently presented an overview of Maine high elevation lakes at the 2009 North American Lake Management Society International Symposium (Baumann and Kahl, 2009). These results will be incorporated in Baumann's MS thesis to be completed in 2010. At least two more publications are expected to result from the thesis. The first will address organic acidity in high elevation lakes (see appendix).

**New developments:** Co-PI Webster is now affiliated with Michigan State University, and will continue her role in publishing on this grant.

### **Recent publications using related project information**

Baumann, A.J. and J.S. Kahl, 2007. Chemical trends in Maine High Elevation Lakes. *LakeLine* 27:30-34.

Campbell, J, J. Hornbeck, M. Mitchell, M. Adams, M. Castro, C. Driscoll, J.S. Kahl, and others, 2004. Input-output budgets for inorganic nitrogen for 24 watersheds in the northeastern United States. *Water Air Soil Pollut.*, 151:373-396.

Dupont, J., T. Clair, C. Gagnon, D. Jeffries, J.S. Kahl, S. Nelson, and J Peckenham, 2005. Estimation of critical loads of acidity in the northeastern US and eastern Canada. *Environ. Monit. Assess.* 109:275-291.

- Hunt, K., J.S. Kahl, J. Rubin, and D. Mageean, 2007. Assessing the science-based needs of stakeholders; a case study on acid rain research and policy. *Journal of Contemporary Water Research and Education*, 136: 68-79.
- Kahl, J.S., J. Stoddard, R. Haeuber, S. Paulsen, R. Birnbaum, F. Deviney, D. DeWalle, C. Driscoll, A. Herlihy, J. Kellogg, P. Murdoch, K. Roy, W. Sharpe, S. Urquhart, R. Webb, and K. Webster, 2004. Response of surface water chemistry to changes in acidic deposition: implications for future amendments to Clean Air Act. *Environmental Science and Technology*, Feature Article 38:484A-490A.
- Lawler, J., J. Rubin, B.J. Cosby, I. Fernandez, J.S. Kahl, S. Norton, 2005. Predicting recovery from acidic deposition: Applying a modified TAF (Tracking Analysis Framework) Model to Maine High Elevation Lakes, *Water Air Soil Pollut.* 164:383-389.
- Nelson, S.J., W.H. Halteman, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, 2010. Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting, and chemical co-variates. *Environmental Science and Technology*, in review.
- Norton, S., I. Fernandez, J.S. Kahl, and R. Reinhardt, 2004. Acidification trends and the evolution of neutralization mechanisms through time at the Bear Brook Watershed, Maine, USA. *Water, Air, Soil, Pollution Focus* 4:289-310.
- Rosfjord, C., K. Webster, J.S. Kahl, S.A. Norton, I. Fernandez, and A. Herlihy, 2007. Anthropogenically-driven changes in chloride complicate interpretation of base cation trends in lakes recovering from acidic deposition. *Environ Sci Technol*, 41:7688 -7693.
- Rosfjord, C., J.S. Kahl, K. Webster, S. Nelson, I. Fernandez, L. Rustad, and R. Stemberger 2006. Acidic deposition-relevant changes in lake chemistry in the EPA Eastern Lake Survey, 1984-2004. Final report to USDA NSRC, Durham, NH. 69 p.

### **Recent presentations using project information**

- Baumann, A.J., and J.S. Kahl, 2009. Assessing the effectiveness of federal acid rain policy using remote and high elevation lakes in northern New England. North American Lake Management Society International Symposium, Hartford, CT, October 29, 2009.
- Kahl, J.S., 2009. Changes in base cations related to long-term changes in Cl distribution in northeastern lakes. Gordon Research Conference, Forested Catchments, July 12-17, 2009, Proctor Academy, NH.
- Kahl, J.S., 2008 (invited). Twenty year changes in spatial patterns of Cl distribution in the northeastern US. NH Water Conference, April, 2008.
- Kahl, J.S., 2007 (invited). Using societal-based incentives to address new threats to New England Lakes. Day-long short course in New England Lake Science Academy, Camp Kieve, Maine. July, 2007.
- Kahl, S., K. Webster, D. Sassan, C. Rosfjord, S. Nelson, M. Greenawalt-Yelle, 2007. Increasing Cl in northeastern surface waters: an indicator of increasing development pressure. Maine Water Conference, Augusta, ME, March 21, 2007.
- Kahl, J.S. 2006 (invited). Acid rain in New England: using high elevation lakes as sentinels of change. Maine Mountain Conference, October 21, 2006. Rangeley, Maine

- Kahl, J.S., *et al.*, 2006 (invited). The design of a national mercury monitoring network: Learning from the EPA acid rain experience. The Eighth International Mercury Conference, Madison WI, August 8, 2006.
- Kahl, J.S. *et al.*, 2006. Obfuscation of trends in base cations by regional salt contamination. Hubbard Brook Committee of Scientists annual meeting, July 12, 2006.
- Kahl, J.S., 2006 (invited). 'Natural and human-derived sources of acidity in Maine Atlantic Salmon Rivers'. Atlantic Salmon Commission workshop on acidity, Bangor ME. April 10, 2006.
- Kahl, J.S., 2005 (invited). The intersection of environmental science and environmental policy. NH Charitable Foundation Lakes Region annual meeting, Meredith, NH, September, 2005.
- Kahl, J.S., 2005 (invited). Tracking response and recovery in surface waters in the northeastern US. Annual meeting of the Ecological Society of America, Montreal, August, 2005.
- Kahl, J.S., and Catherine Rosfjord, 2005 (invited). Acid rain and the Clean Air Act in the northeastern US. Annual meeting of the NH-ME Androscoggin River Watershed Council, Bethel, June, 2005
- Kahl, J.S., 2005 (invited). Developing a lake research agenda for NH. NSF workshop on lake research infrastructure in the northeast, Colby Sawyer College, April 2005.
- Kahl, J.S., S. Nelson, and A. Grygo, 2004. Surface water chemistry data for the northeastern US for interpreting climate and acid rain trends. Northeast Ecosystems Research Consortium meeting, Durham, NH, October, 2004.
- Kahl, J.S., K. Webster, M. Diehl, and C. Rosfjord, 2004. Successes of the Clean Air Act Amendments of 1990. Maine Water Conference invited plenary talk, Augusta, ME, 2004.
- Kahl, J.S. and K. Johnson, 2004. Acid-Base Chemistry and Historical Trends in Downeast Salmon Rivers. Maine Water Conference, Augusta ME, April 2004.
- Kahl, J.S., 2004 (invited). The Clean Air Act Amendments of 1990; testing a program designed to evaluate environmental policy. Lecture, Colby College. April, 2004
- S.J. Nelson, J.S. Kahl, N.C. Kamman, D.P. Krabbenhoft, W.H. Halteman, 2009. (Poster) Predicting mercury concentrations in northeast lakes using hydrogeomorphic features, landscape setting and chemical co-variates. Gordon Research Conference, Forested Catchments, July 12-17, 2009, Proctor Academy, NH.
- Nelson, S.J., I. Fernandez, S. Norton, B. Wiersma, L. Rustad, J.S. Kahl, 2008. The Bear Brook Watershed in Maine: Long-term research supporting climate change inquiry. Hydroclimatic effects on ecosystem response: participant workshop, Syracuse, NY, September 19, 2008.
- Nelson, S.J., N. Kamman, D. Krabbenhoft, J.S. Kahl, K. Webster, 2008. Evaluating spatial patterns in mercury and methyl mercury in northeastern lakes: Landscape setting, chemical climate, and human influences. Northeastern Ecosystem Research Cooperative Conference, Durham, NH, November 12-13, 2008.
- Nelson, S.J. 2008. Evaluating spatial patterns in mercury and methyl mercury in northeastern lakes: landscape setting, chemical climate, and human influences. Maine Water Conference, Augusta, ME, March 19, 2008.



*Increasing organic acidity as part of recovery from acidic deposition in Maine high elevation lakes.*

Abstract

Recovery from acidic deposition in the northeastern U.S. has led to improvements in surface water quality in some of the most affected waters. Nowhere is this more apparent than in the high elevation lakes of Maine (HELM). An important consequence of decreased acid rain has been an increase in dissolved organic carbon (DOC) in recovering surface waters across the northern hemisphere. This result has led to a transition from inorganic (acid rain) to natural (DOC) sources. The rapid response of the acid sensitive HELM lakes to changes in deposition makes them well suited for assessing increased DOC as part of recovery from acid rain. The ‘Sulfate Fraction’ (SF, the relative contribution of  $\text{SO}_4$  to the total amount of anions) has decreased ~ 40% in these lakes since the mid 1980’s, yet no significant change in pH has occurred (Figure 1). Over the same time period, DOC has been increasing at ~0.1mg/L/yr (~+20% since the mid-1980s), making up an increasing portion of the ionic strength of the HELM waters (Figure 2) that are simultaneously becoming more dilute (Figure 3). This shift in acidity is responsible for the relatively unchanged pH status of acid sensitive waters despite significant decreases in inputs of acid rain to the systems. Our conclusion is that while recovery in ANC is still incomplete, recovery in pH may be nearing completion due to replacement of mineral acidity with organic acidity (Figure 2). This conclusion is consistent with ample paleolimnological evidence that shows that lakes classified as ‘acidified’ in the 1980s ( $\text{pH} < 5$ ) typically had pre-historical pH values that were between pH 4.8 and 5.8. pH ‘recovery’ of these systems will (has?) been represented by modest increases in pH because of the acidic nature of these systems long before human impact from acidic deposition. The policy-relevant importance of these results is recognition that natural organic acidity must be included in critical load calculations, which will reduce the amount of S reduction needed in emissions/deposition to meet pH targets.

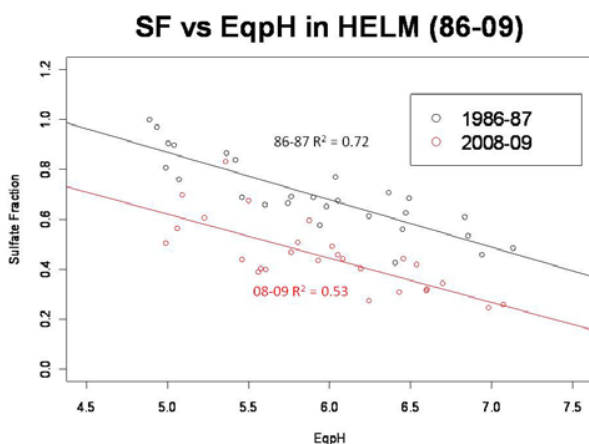


Figure 1. Reduction in the contribution of sulfate to total anion concentration, but without an increase in pH

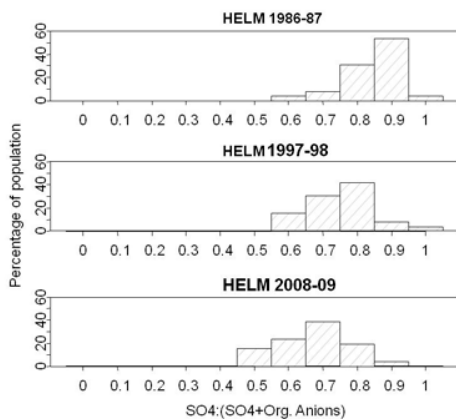


Figure 2. Temporal evolution towards increasing importance of organic acidity in HELM lakes.

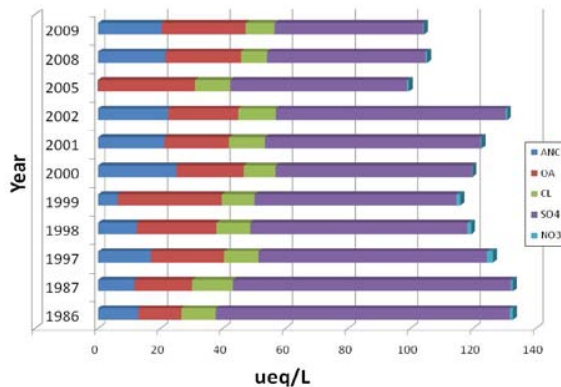


Figure 3. Changes in ionic composition of HELM lakes, showing reduction in ionic strength.

Appendix II. Draft abstract from MS candidate Doogan thesis  
(supported under separate funding from this IAG)

*Temporal Trends and Landscape Controls on Al in the Hubbard Brook Experimental Forest and  
White Mountains of NH*

Christian Doogan, MS candidate, Plymouth State University, 2010

Draft Abstract

Stream chemistry is influenced by many factors such as vegetation cover, precipitation chemistry, soils, geology, and mineral weathering. The differences in the distribution of flow paths and water residence times throughout the landscape also affect stream chemistry. Acidification of stream water poses a possible threat to many species and the extent of this impact in the White Mountains of New Hampshire remains unclear despite abundant historical information collected over the past 30 years. Motivated by the challenge of understanding the relationship of the landscape to stream chemistry in this region, this project sought to a) describe the stream chemistry variability in the region and its relationship to the landscape, and b) determine trends in episodic and baseflow Al concentrations. The objective was to investigate stream chemistry under contrasting high to low flow regimes of watersheds varying in basin size and spatially across the region to investigate a wide range of landscape characteristics. This analysis was done by comparing stream chemistry samples collected in a synoptic strategy under spring high and summer low flows to a) landscape variables derived from terrain analysis of surface topography, and b) to historical data from previous surveys.

Stream chemistry from a second data set collected under non-event conditions at Hubbard Brook was compared to similar landscape variables derived from terrain analysis. The Hubbard Brook dataset provided an opportunity to test the landscape variables on a large number of nested sample locations collected under higher spatially resolution including basin sizes far smaller than the region wide analysis. Landscape variables were compared with stream chemistry of both datasets by Spearman rank correlations and linear stepwise regression analysis.

Results from this study show that although many relationships could be found between the landscape variables analyzed and stream chemistry, many were only weakly correlated. The landscape variables could only partially predict stream chemistry under either high or low flow for the 2008 White Mountain dataset or under the non-event fall 2001 Hubbard Brook Valley-Wide dataset. At best, 60% of stream chemistry variables could be explained for either dataset by the landscape variables. However, it was found that many of the landscape variables

correlated with stream chemistry under spring high flows were also correlated to summer low flow so that no distinct difference in the landscape variables important to flow regime was observed. Percent till calcium concentration was found to be an important landscape variable for the White Mountain region. For Hubbard Brook it was elevation and forest cover that were the most important landscape variables. Forest cover was correlated to total aluminum (Al) and inorganic aluminum ( $Al_i$ ) for both the White Mountain region and at Hubbard Brook. The results show that easily derived topographic data and simple terrain analysis cannot characterize landscape control on stream chemistry variability and the landscape variables analyzed do not act as accurate surrogates for the hydrologic processes that influence stream chemistry.

## Grant No. 07HQGR0172 Watershed Assessment of New Boston Air Force Base

### Basic Information

<b>Title:</b>	Grant No. 07HQGR0172 Watershed Assessment of New Boston Air Force Base
<b>Project Number:</b>	2007NH102S
<b>Start Date:</b>	8/23/2007
<b>End Date:</b>	8/22/2009
<b>Funding Source:</b>	Supplemental
<b>Congressional District:</b>	01
<b>Research Category:</b>	Climate and Hydrologic Processes
<b>Focus Category:</b>	Water Quantity, Water Quality, Hydrology
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	William H H. McDowell

### Publications

There are no publications.



**Project:** Watershed Assessment of New Boston Air Force Station to be completed by Emily DiFranco of the University of New Hampshire under the direction of Dr. William H. McDowell

**Problem Statement:**

New Boston Air Force Station (NBAFS), located in a rapidly-growing region of southern New Hampshire, has a history of past use that has potentially contaminated the water resources on the site as well as altered the site's hydrology. Past use includes a landfill as well as training operations during WWII, primarily for use as a target site for bombing runs. Both live and inert ordnance were used during training, with thousands of bombs dropped. Many bombs detonated during training exercises, but some live ordnance remained on site after training ceased. Most of this ordnance has been identified and detonated in place over the last few decades. The impacts of these past land uses on water resources are largely unknown. Alteration of soils and groundwater flow paths in the basin, as well as contamination from the ordnance and landfill leachate may have occurred. In the region, the uncertainty over the possible impacts of Air Force operations poses a water resources management challenge. Thus, better understanding of the hydrology and water resources issues on NBAFS will benefit regional management of water resources.

**Overall Objective:** Assess the quantity, quality, and distribution of surface and groundwater resources of NBAFS.

**Specific Objectives:**

- 1). Evaluate surface water flow and develop a delineated watershed profile showing surface water movement.
- 2). Inventory the annual inputs (precipitation) and outputs (evapotranspiration and streamflow) for NBAFS using the hydrologic model BROOK90.
- 3). Identify groundwater flow paths and lake level fluctuations throughout the year.
- 4). Identify potential contaminant migration through ground and surface water flow paths using water quality data from Shaw Environmental.

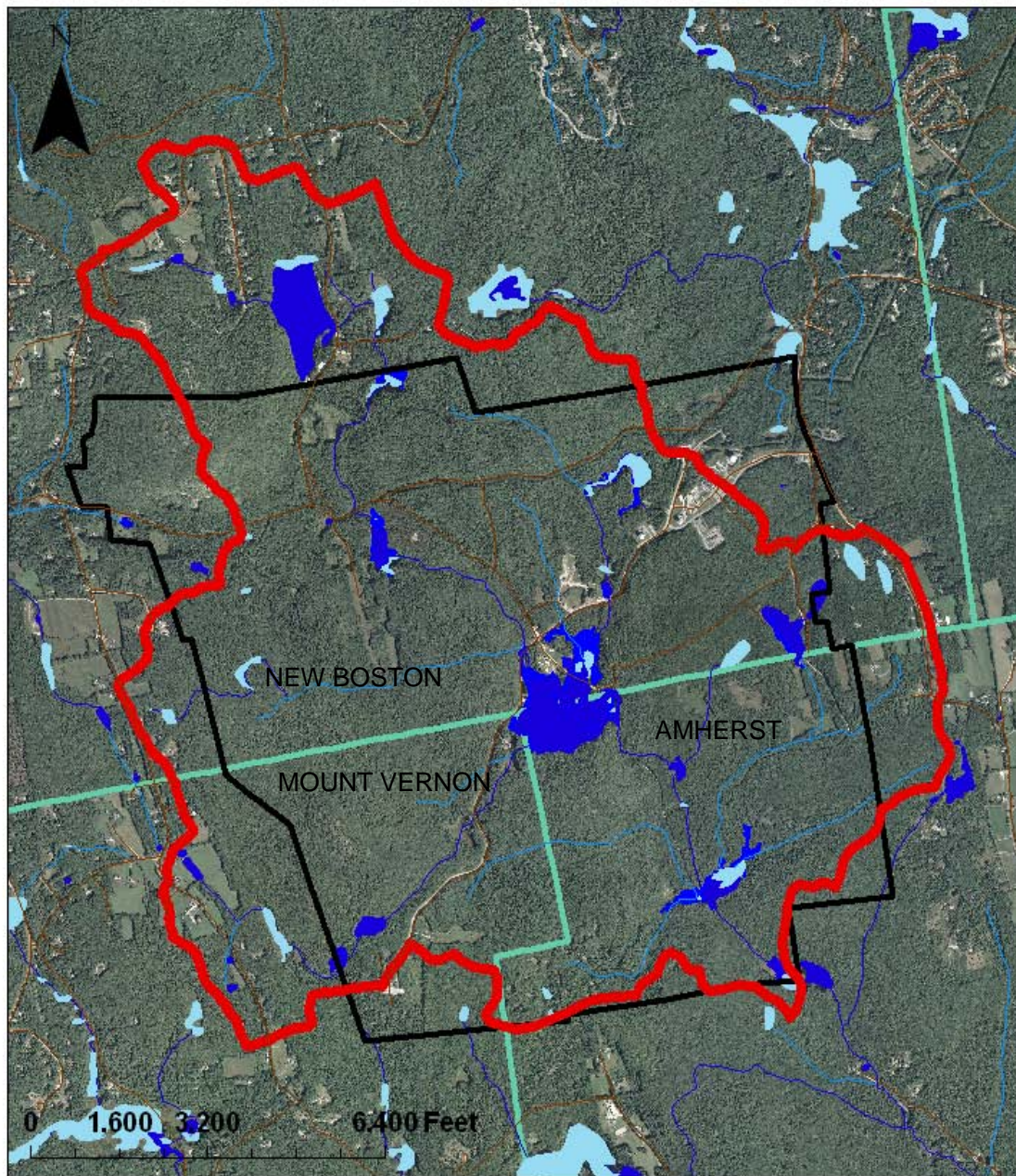
**Objective 1:** Evaluate the surface water flow and develop a delineated watershed profile showing surface water movement.

**Deliverable 1:** Watershed delineation and surface water flow maps:

- 1). Watershed delineation: Aerial and topographic views
- 2). Surface water flow map: Aerial, topographic, and water body view

**Summary:**

The New Boston Air Force Station watershed is approximately 3,454 acres or 5.4 miles<sup>2</sup> in area and includes the towns of New Boston, Amherst, and Mont Vernon, NH (Figures 1-1 and 1-2). The watershed drains to the southeast with most of the surface water on the base reaching Joe English Pond (JEP) and draining into Joe English Brook (JEB) (Figures 1-3 and 1-4). The upper northeast and northwest corners of NBAFS fall outside of the watershed boundaries.



**Legend**

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- Roads

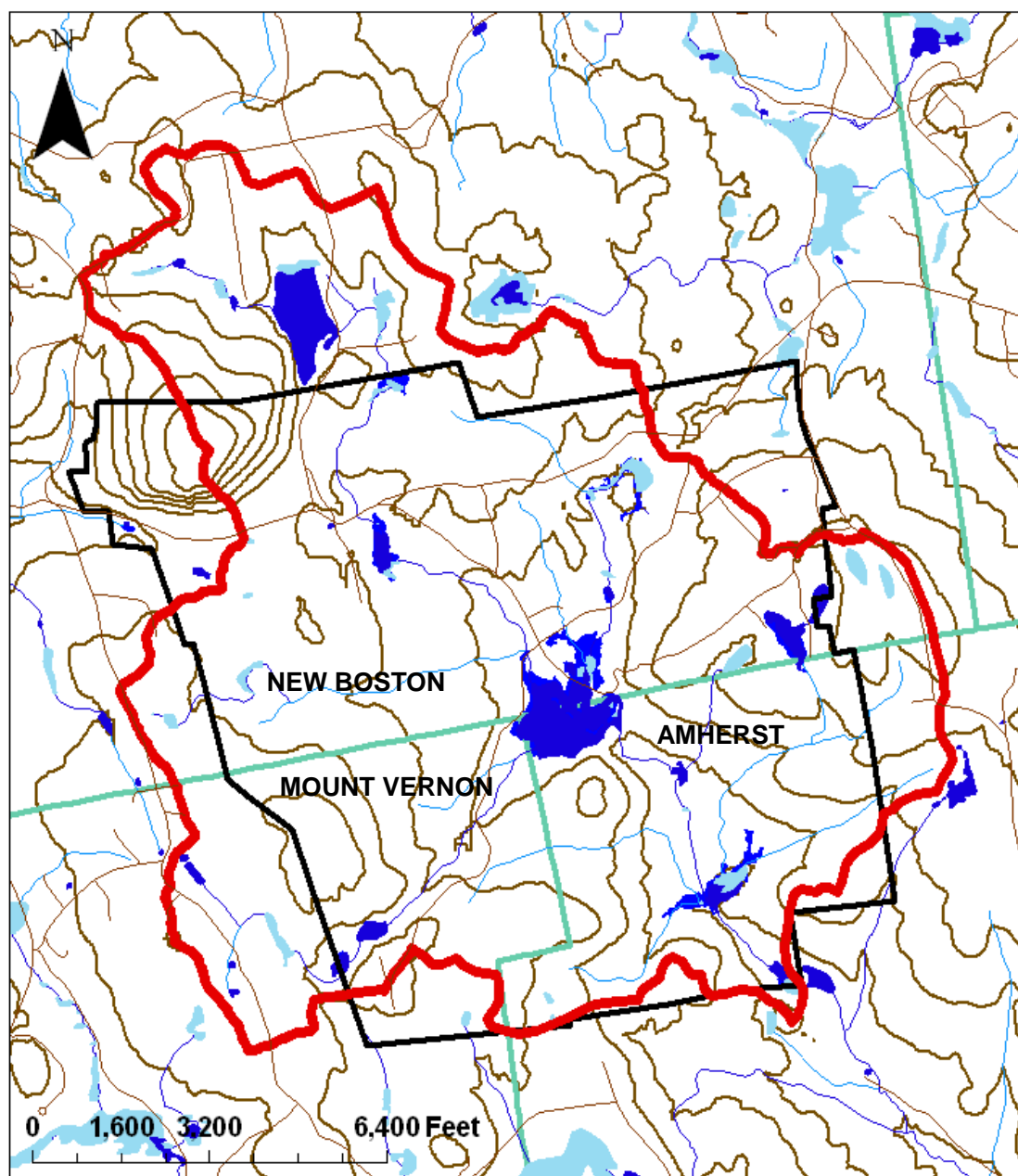
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**Figure 1-1: Watershed Boundary  
Aerial View: New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
Aerial Photo: NH Granit



**Legend**

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- Roads

**1:30,000**

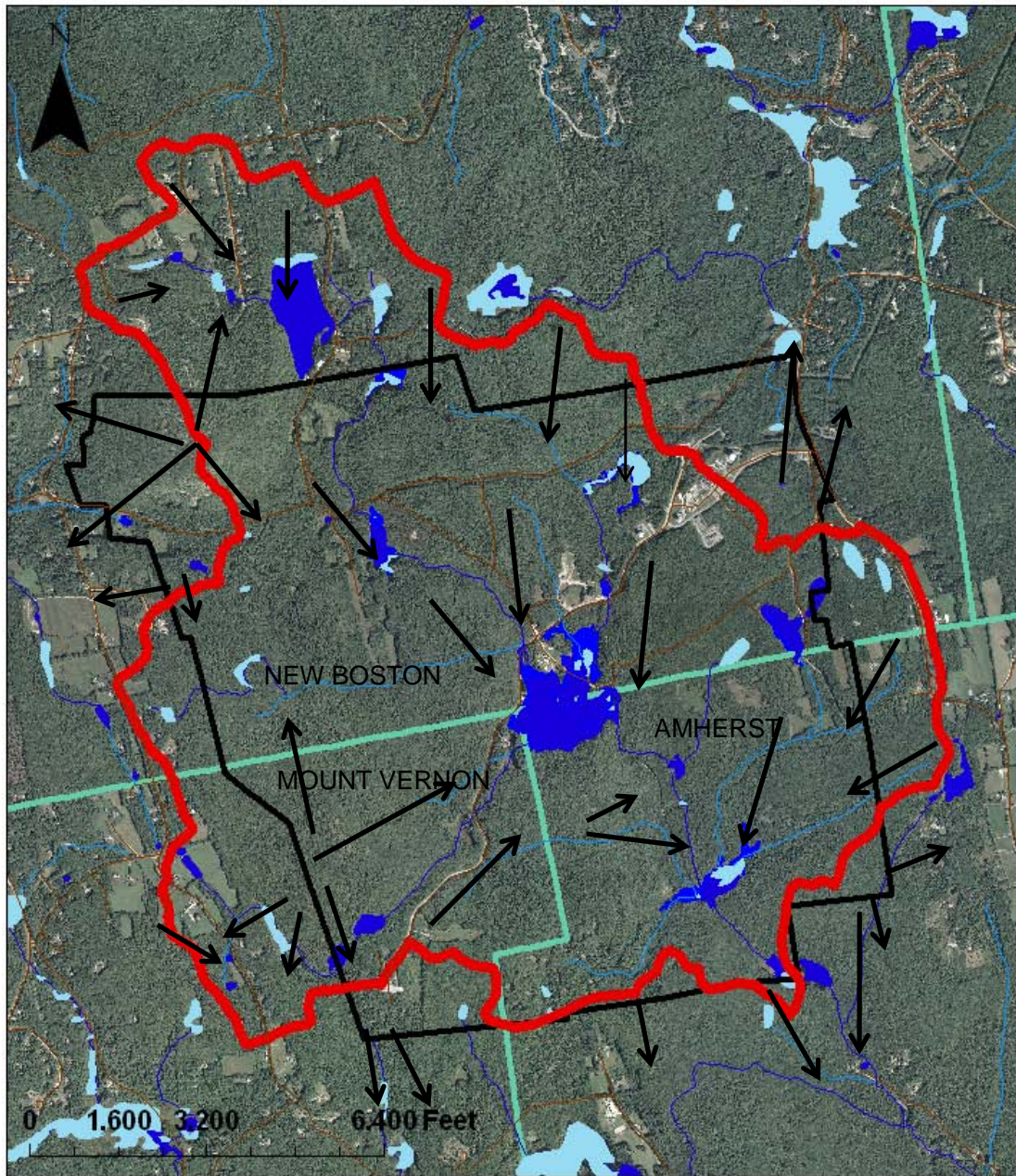


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**Figure 1-2: Watershed Boundary  
Topographic View  
New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
100 ft Contours: Shaw Environmental, Inc.





**Legend**

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- Roads

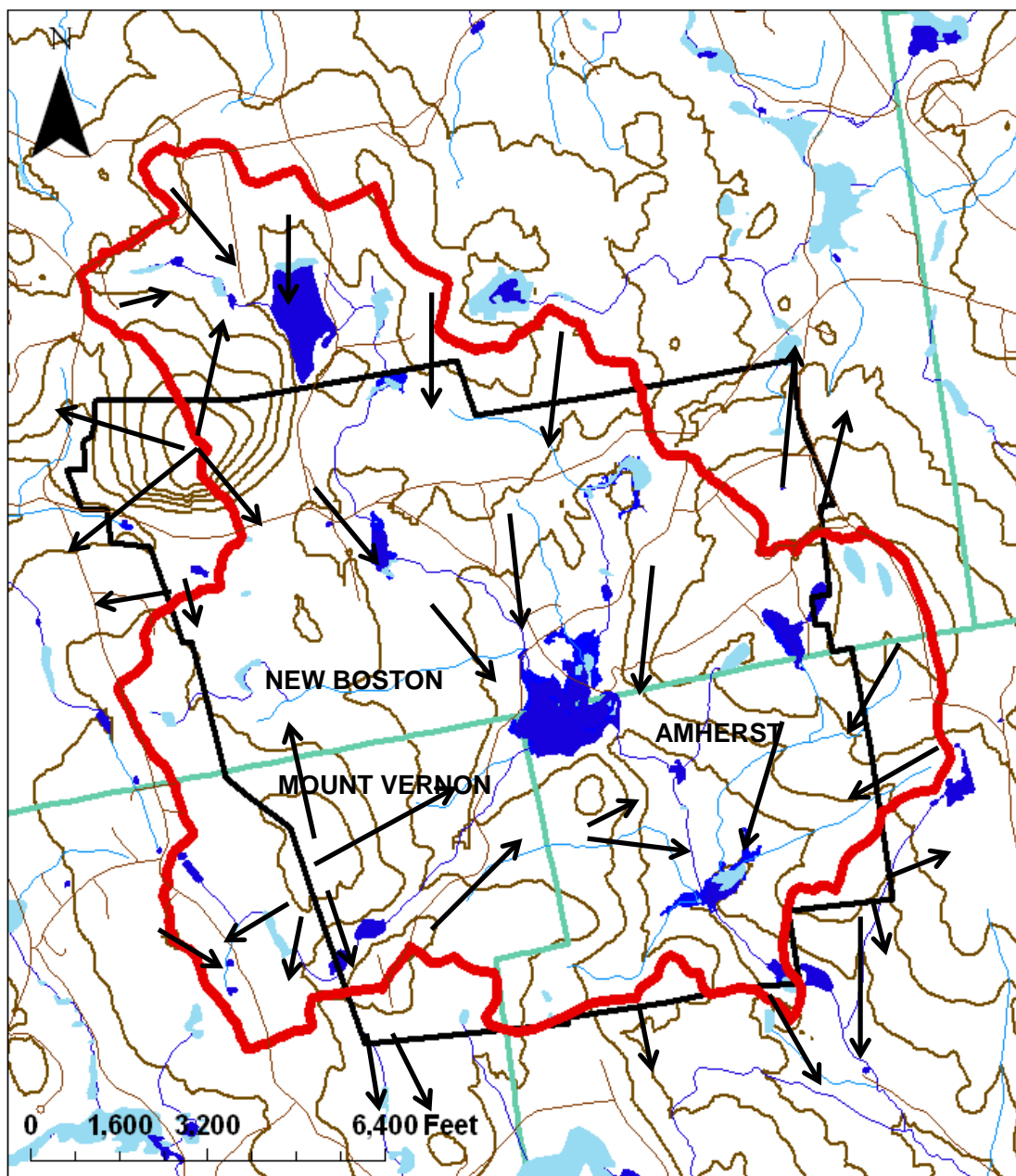
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**Figure 1-3: Surface Flow**  
**Aerial View: New Boston Air Force Station**

NH Water Resources Research Center  
 Hydrology and Watershed Analysis NBAFS  
 Aerial Photo: NH Granit



**Legend**

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- Roads

**1:30,000**



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**Figure 1-4: Surface Flow  
Topographic View  
New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
100 ft Contours: Shaw Environmental, Inc.

**Objective 2:** Inventory the annual inputs (precipitation) and outputs (evapotranspiration and streamflow) for NBAFS using the hydrologic model BROOK 90.

**Deliverable 2:** Completion of BROOK 90 model

- 1). Detailed description of model and parameters
- 2). Graphical and tabular presentation of the water budget for NBAFS from 11/07- 2/09

**Model Summary:**

BROOK 90 is a simulation model for evaporation, soil water, and streamflow developed by C. Anthony Federer. It was originally designed for use at the Hubbard Brook Experimental Forest in New Hampshire, but has since been used in watersheds in places as diverse as Arizona, California, Pennsylvania, and New England. BROOK 90 has been cited in over 30 publications. This model is parameter-rich and provides estimates of difficult to measure variables of a local water budget, such as evapotranspiration and soil water movement, at a daily-time step. Streamflow can be modeled making BROOK 90 particularly useful in areas that may be inaccessible to continuous on-site field work provided there is some background knowledge of watershed characteristics.

**Input variables:**

BROOK 90 input files allow for the input of the following variables (only starred variables are required):

- 1). Year\*
- 2). Month\*
- 3). Day of the month\*
- 4). Solar radiation on a horizontal surface ( $\text{MJ/m}^2$ )
- 5). Maximum temperature for the day (Celsius)\*
- 6). Minimum temperature for the day (Celsius)\*
- 7). Average vapor pressure for the day (kPa)
- 8). Average wind speed for the day (m/s)\*
- 9). Precipitation for the day (mm)\*
- 10). Measured streamflow for the day (can be predicted by the model if there is no measured streamflow available).

For this study, starred variables were obtained from the weather station already in place on NBAFS. The weather station was calibrated for local latitude and elevation in November 2007 and a heating element was installed to allow for winter precipitation to be measured. Monthly data was checked against local weather data from Manchester Airport. Any gaps in data were filled in from this data set.



## Input Parameters:

*Location Parameters:* These parameters are site specific. Latitude, slope (overall slope of watershed from highest to lowest point) and aspect (direction the watershed faces) of the watershed are required and were estimated from topographic and watershed maps of NBAFS.

*Flow Parameters:* These parameters are also site specific and affect infiltration and drainage. The initial values provided in the model were designed for Hubbard Brook Watershed 6, a moderately steep, forested watershed. Parameters were changed only slightly, as most of the parameters were within a range of values appropriate for NBAFS. Many of these parameters were determined from suggestions provided in the BROOK 90 documentation for specific types of geographic locations. The percent of impervious surfaces influence the timing of peak flows and were estimated from land cover maps of the installation.

*Canopy Parameters:* These parameters depend on the type and height of the dominant vegetation within the watershed and are necessary to determine the amount of water lost to transpiration. Many of these parameters were determined from provided tables in the BROOK 90 documentation for specific types of land cover.

*Soil Parameters:* These parameters are important to determine infiltration rates and were determined from soil maps created by Shaw Environmental, Inc.

*Fixed Parameters:* These parameters were set in the original model, and it was not advised to change them for a specific location.

## Output Variables:

BROOK 90 uses the inputted weather data to produce modeled estimates for the following variables:

- **Discharge** (mm/day, month, year): amount of water leaving the watershed through a stream outlet (in this case, JEB)
- **Evapotranspiration** (mm/day, month, year): amount of water returned to the atmosphere through a combination of evaporation and transpiration (from plants)
- **Soil water** (mm/day, month, year): amount of water stored in the soil
- **Groundwater** (mm/day, month, year): amount of water stored in the groundwater



## Conclusions:

This model allows for an understanding of the water budget of a watershed and allows for predominant pathways of water movement throughout the year to be determined. Assuming water enters the watershed solely through precipitation (measured), the major losses are due to discharge and evapotranspiration (modeled) and the major storage reservoirs are soil water and groundwater (modeled).

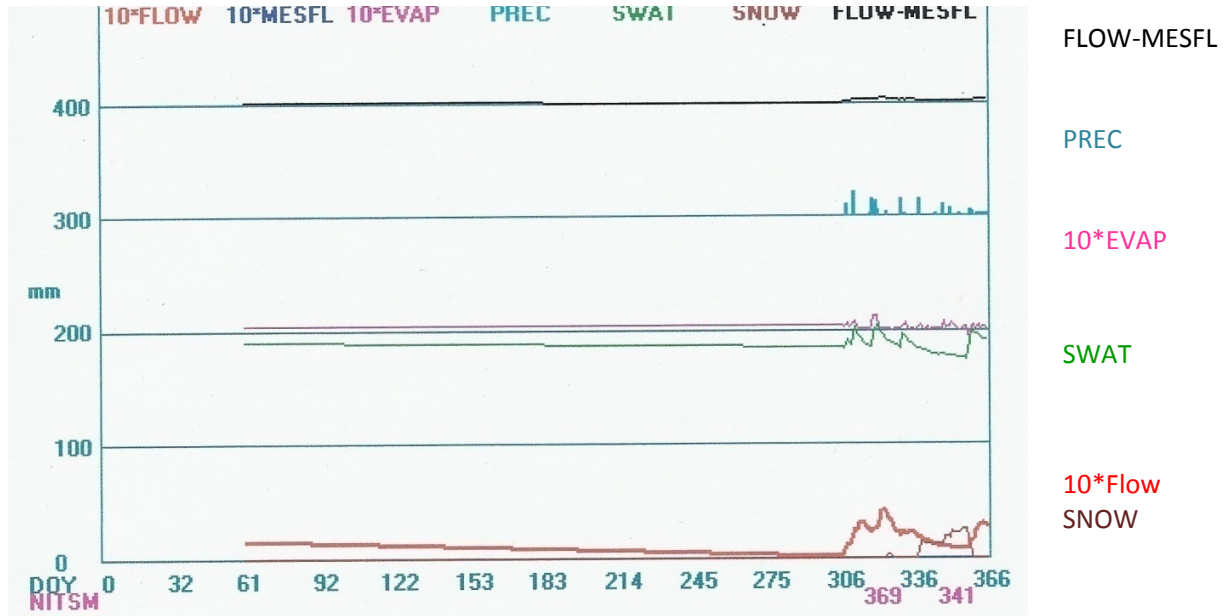
Most water that enters the base leaves as discharge through the outlet JEP (Table 2-1). Precipitation is highest in the spring and fall (2008). Highest discharge occurs in March 2008 which can be expected due to the spring melt. Lowest discharge occurs in the summer months (2008) as more water is removed from the soil by plants and evapotranspiration is highest (due to increased solar radiation and temperatures). In general, evapotranspiration is lowest in the winter months, as plants are dormant and temperatures are low. Soil water and groundwater are lowest in the summer which is expected due to lower precipitation and higher demand from plants.

**Table 2-1: Monthly water budget for New Boston Air Force Station (November 2007-February 2009)**

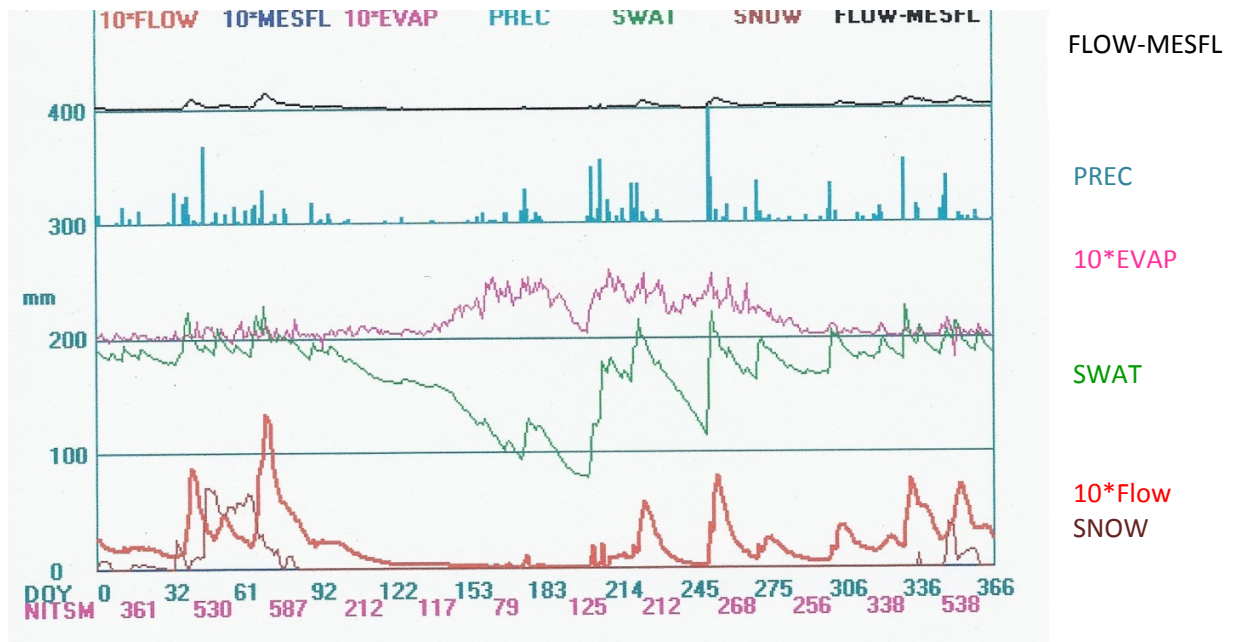
Month	Year	Precipitation (mm/month)	Discharge (mm/month)	Evapotranspiration (mm/month)	Soil Water (mm/month)	Groundwater (mm/month)
November	2007	87.86	73.24	9.11	186.98	5.39
December	2007	55.5	45.14	5.51	189.82	6.27
January	2008	44.2	52.52	7.25	179.14	2.5
February	2008	191.76	110.2	13.86	188.38	5.94
March	2008	125.73	165.52	13.9	189.47	5.83
April	2008	23.1	38.72	17.32	161.93	0.79
May	2008	14.16	7.39	35.97	133.6	0.22
June	2008	105.65	4.06	116.38	119	0.03
July	2008	158.48	9.37	96.62	169.32	2.21
August	2008	121.91	53.54	107.36	132.22	0.32
September	2008	227.04	73.24	91.92	188.51	5.9
October	2008	71.12	41.84	24.77	190.51	8.41
November	2008	108.71	82.11	9.45	194.13	11.62
December	2008	108.71	123.75	7.99	185.54	5.64
January	2009	51.29	28.92	6.86	172.13	1.3
February	2009	35.29	38.77	9.82	190.62	4.6

Graphical representation of the water budget for NBAFS throughout the study period is shown in Figures 2-1, 2-2, and 2-3.\*

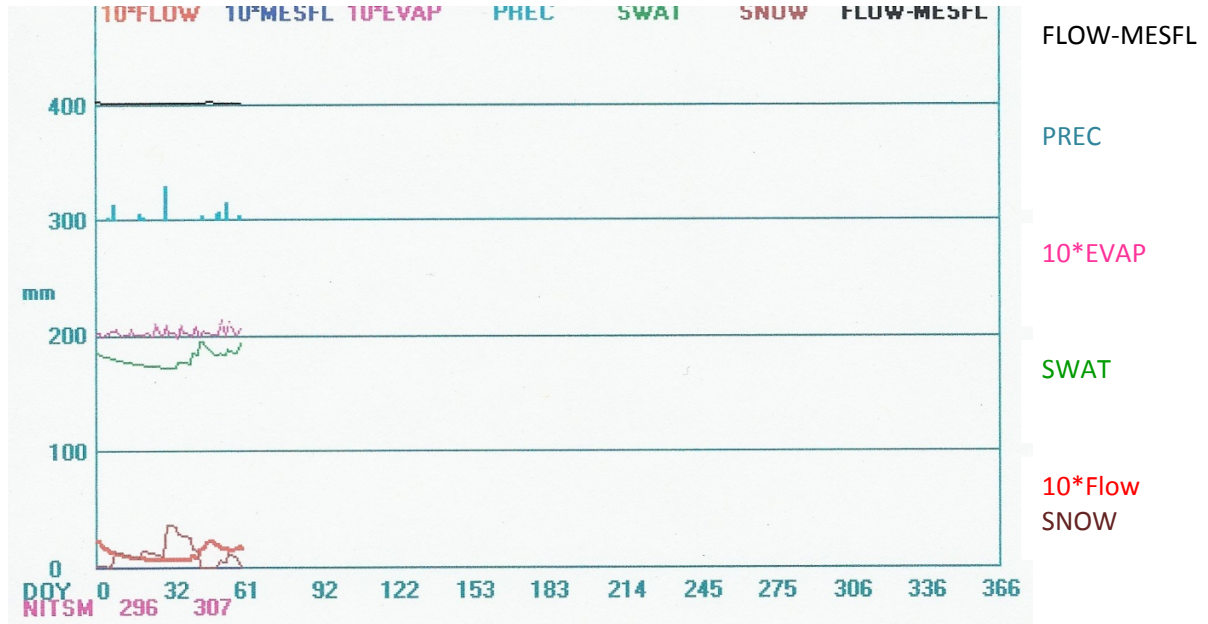
**Figure 2-1: Water budget for NBAFS watershed for November and December 2007**



**Figure 2-2: Water budget for NBAFS watershed for 2008**



**Figure 2-3: Water budget for NBAFS for January and February 2009**



\*  $10 \times \text{FLOW} = 10 \times \text{Discharge at the outlet}$ ;  $10 \times \text{MESFL} = 10 \times \text{any measured flow at outlet}$  (as this variable is always 0 for this case, it is absent from the graph);  $10 \times \text{EVAP} = 10 \times \text{water lost to evaporation}$ ;  $\text{PREC} = \text{amount of precipitation}$ ;  $\text{SWAT} = \text{amount of stored in the soil}$ ;  $\text{SNOW} = \text{amount of water held as snowpack}$ ;  $\text{FLOW-MESFL} = \text{difference between the estimated discharge and measured discharge}$  (as there was no measured discharge, this variable can be ignored).

**Objective 3:** Identify groundwater flow paths and JEP level fluctuations throughout the year.

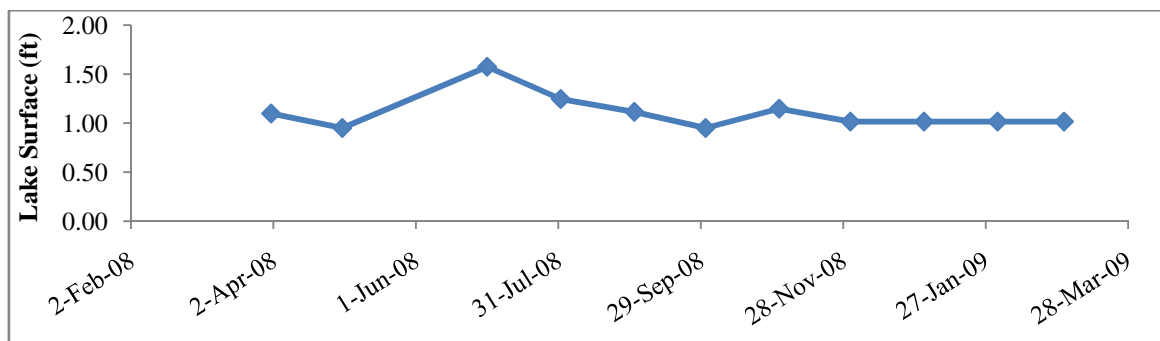
**Deliverable 3:** Completion of identification of groundwater flow paths

- 1). Graphical presentation of annual JEP surface level fluctuation
- 2). Graphical presentation of monthly groundwater depths relative to JEP surface elevation
- 3). Map of monthly groundwater flow paths within watershed
- 4). Map of surrounding private and public wells (wells that may be affected will be noted)

**Annual lake surface level fluctuation:**

The surface of JEP fluctuated 0.623 ft from April 2008 to March 2009. JEP was highest in July 2008 and lowest in May and October 2008. From December 2008 to March 2009, JEP was visibly frozen and did not fluctuate (Figure 3-1).

**Figure 3-1: JEP Surface Fluctuation from April 2008 to March 2009 (measured at Daughton's Landing)**



**Annual relative groundwater elevation fluctuations:**

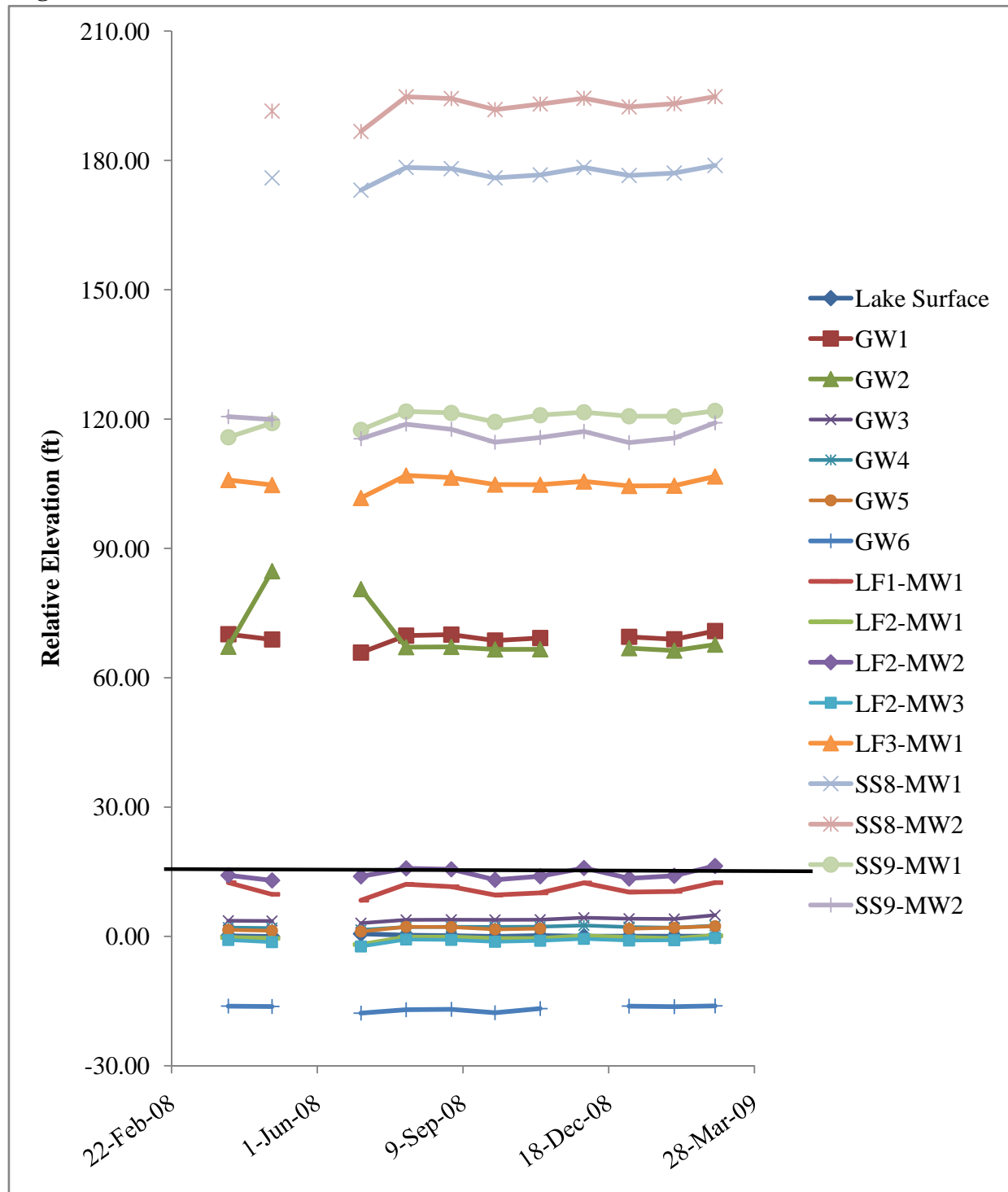
The depth to groundwater (DTWT) was measured once a month from April 2008 to March 2009 from fifteen wells scattered throughout the NBAFS (Figure 3-4). Surface level of Joe English Pond was also measured throughout this period. Wells located close to JEP as well as the lake itself were surveyed together to determine relative elevation of groundwater throughout the year. Wells located farther uphill in the watershed were not surveyed as their locations were well above JEP, and the accuracy of surveying was not necessary in these cases as a margin of error of  $\pm 10$  ft was deemed acceptable for these wells. Previous elevation data from Shaw Environmental (determined to have a margin of error of  $\pm 10$  ft ) was used to determine relative elevation to the lake surface for these wells.

Relative elevation of groundwater to JEP surface can be used as an indication of groundwater flow direction. If the relative elevation of the groundwater for a sample date is above the relative elevation of JEP for that date, water is expected to flow from the well towards

the lake. If the relative elevation of the groundwater for a sample date is below the relative elevation of JEP for that date, water is expected to flow from JEP towards the well. In the graphs below, most of the groundwater in the studied wells flows towards JEP on the base for most of the year (Figures 3-2 and 3-3). However, by examining the wells closer to JEP, three wells (GW-6, LF2-MW1, LF2-MW3) consistently have groundwater below the level of the lake, indicating these wells receive water from JEP (Figure 3-3).

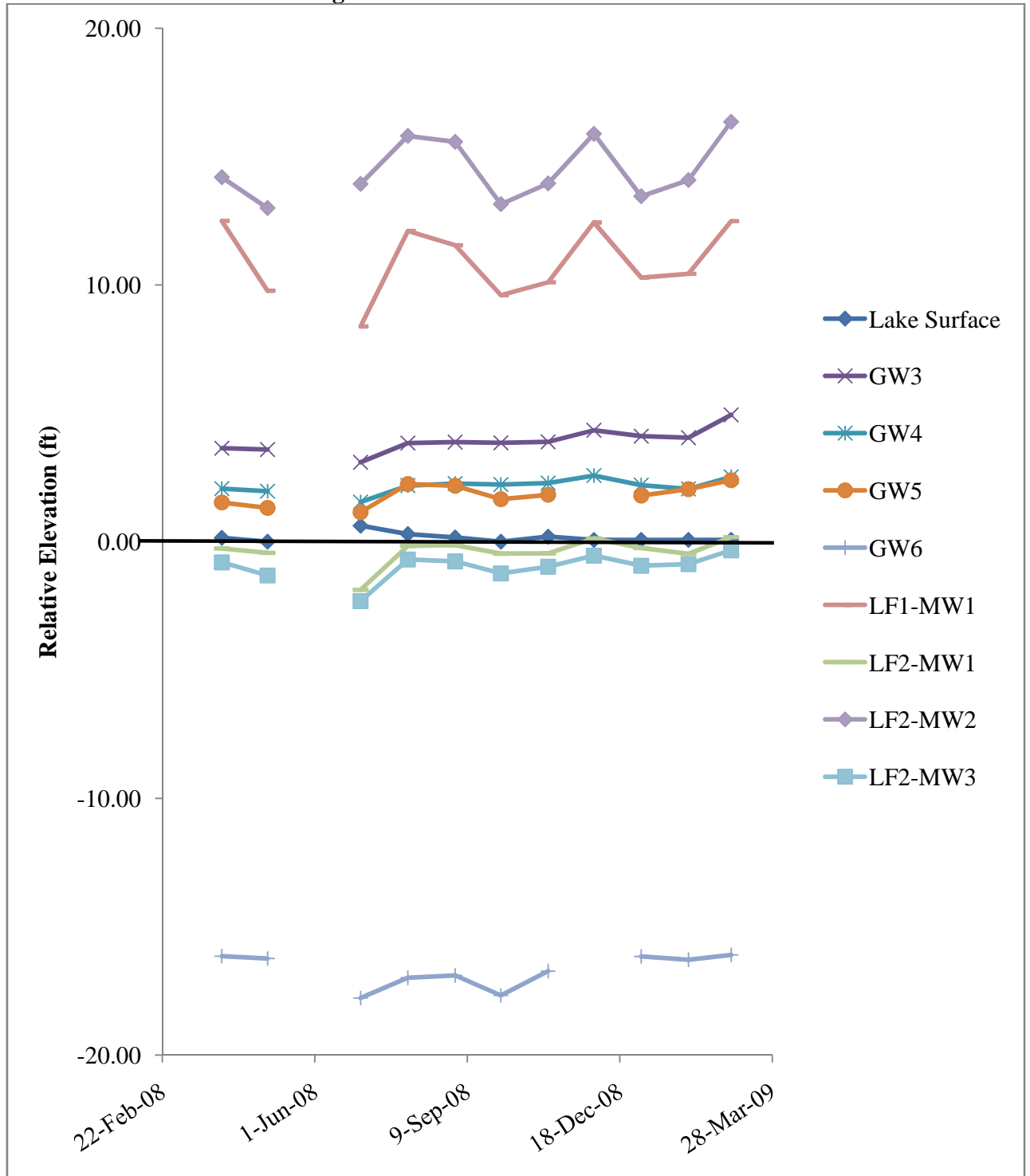
The DTWT varies throughout the year due to changes in precipitation, water removal by plants, and evaporation. The DTWT generally decreases (water table becomes closer to the surface) in the spring as snow melts and precipitation increases. The DTWT generally increases (the water table lowers) in the summer and fall as more water is removed by plants and processes such as evaporation increase. In the late fall, the DTWT often decreases from the summer as there is less demand from plants and less evaporation. There is also often more precipitation at this time. Groundwater in all fifteen wells on the NBAFS followed a similar temporal pattern (Figure 3-2) though this pattern did not cause changes in groundwater flow direction.

**Figure 3-2: Relative elevation of groundwater level in each well to the elevation of Joe English Pond\***



\* From April 2008 to March 2009 (if relative groundwater elevation is below relative lake elevation (approximately 0 ft, note reference line), water drains from Joe English Pond towards that well)

**Figure 3-3: Relative elevation of groundwater level in each well located near Joe English Pond to the elevation of Joe English Pond\***



\* From April 2008 to March 2009 (if relative groundwater elevation is below relative lake elevation (approximately at reference line), water flows from Joe English Pond towards that well)

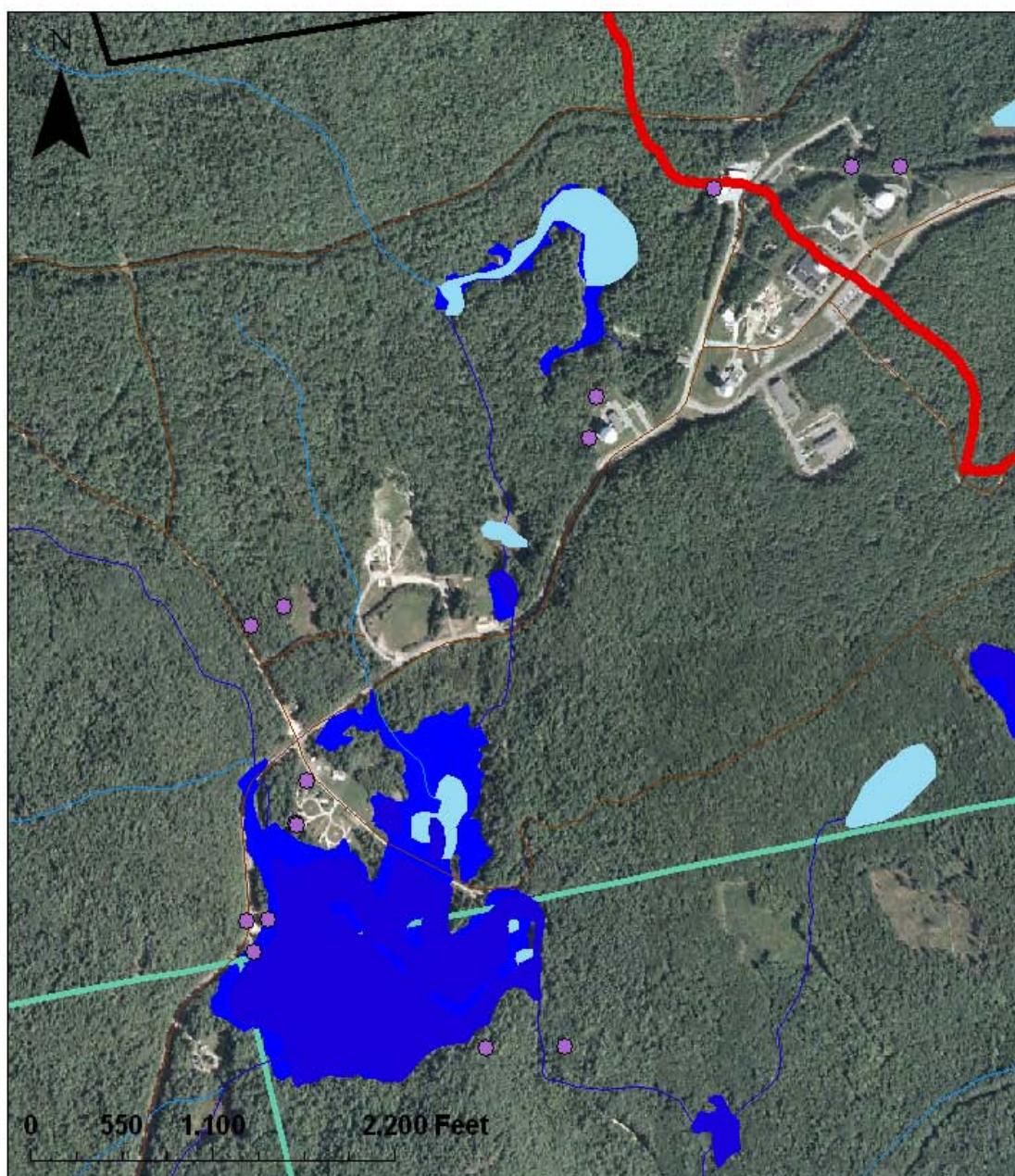
### **Monthly groundwater flowpaths within the NBAFS watershed:**

Overall, groundwater flow direction determined from DTWT in the monitoring wells appears to follow topographic contours and flows southeast towards the outlet (Figure 3-5). As such, most groundwater within the northern section of the NBAFS installation boundaries drains towards JEP. However, as the watershed boundary does not match up exactly with the installation boundaries, it is likely that some groundwater is leaving NBAFS. The southeast corner of NBAFS includes the outlet of JEP and most likely transfers both surface and groundwater off-site. Further, the northeast corner of the base, near wells SS9-MW1 and SS9-MW2, is located outside of the watershed boundary. Though it is clear that water from JEP is not flowing towards those wells, it is unclear with the data collected if the groundwater in those wells is flowing towards the lake by crossing the watershed boundaries, or if the groundwater is flowing northeast (similar to surface flow) and off of the boundaries of NBAFS. Based on the direction of flow determined for NBAFS, it is more likely that the groundwater is flowing offsite and follows surface flow paths.

### **Surrounding Private and Public Wells:**

The location of private and public wells in New Boston, Amherst, and Mont Vernon were obtained from the New Hampshire Department of Environmental Services (Figure 3-6). Though most wells lie outside of the watershed boundary, it is likely that groundwater originating on the base may be affecting public and private wells in some areas. For instance, the outlet of the watershed (and the southeast corner of NBAFS) carries with it both surface and groundwater from the entire watershed. Any of the wells located along the stream outlet of the watershed are likely receiving water from the river at some point throughout the year. Further, any well located directly outside of the NBAFS boundaries that lie outside of the watershed boundary may also be affected. All wells potentially receiving water from NBAFS are noted on the groundwater map (Figure 3-7).





#### Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFS Wells
- Roads

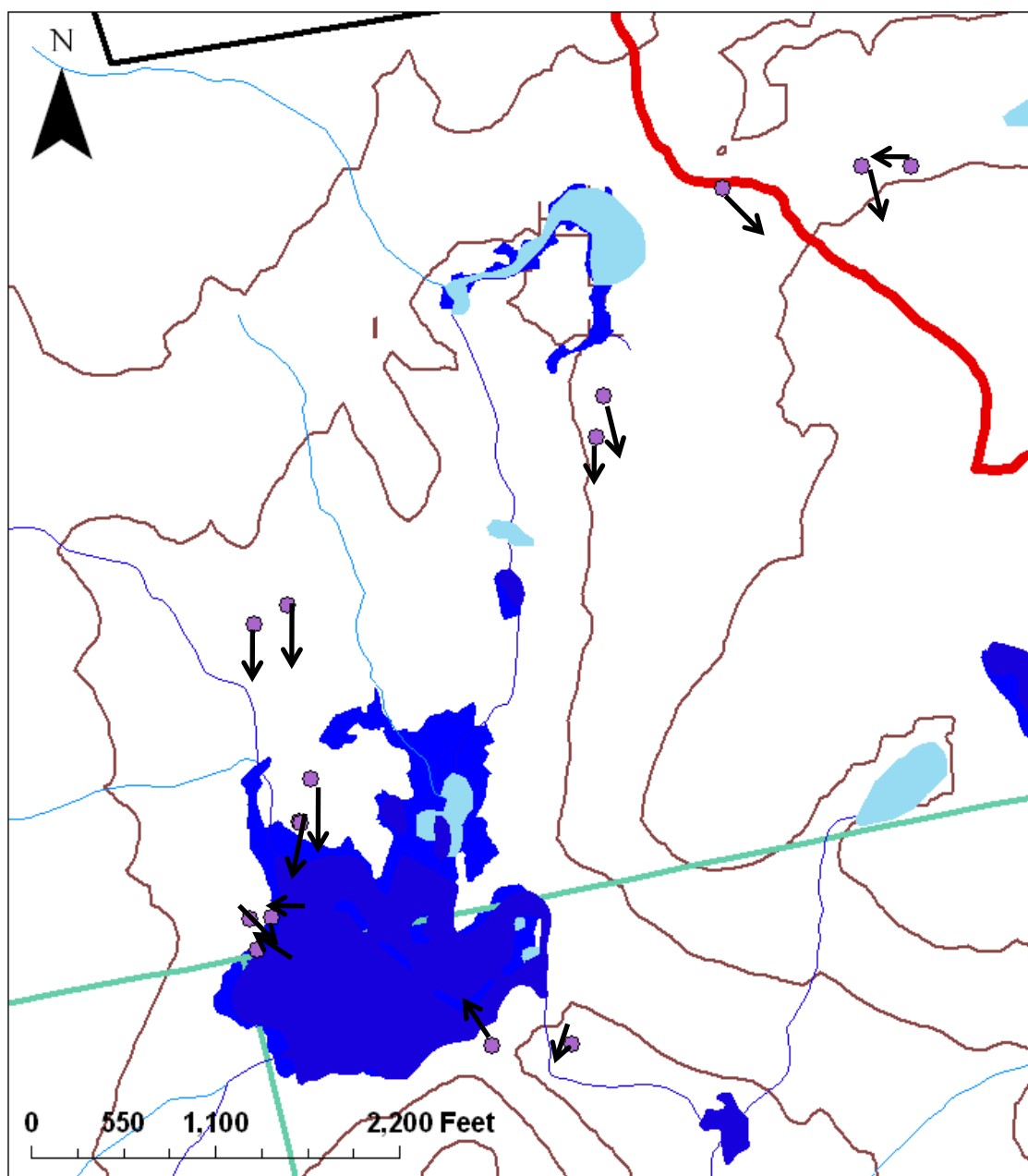
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**Figure 3-4: Groundwater Monitoring Wells  
Location: Aerial View  
New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
Aerial Photo: NH Granit



#### Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFS Wells

1:10,000

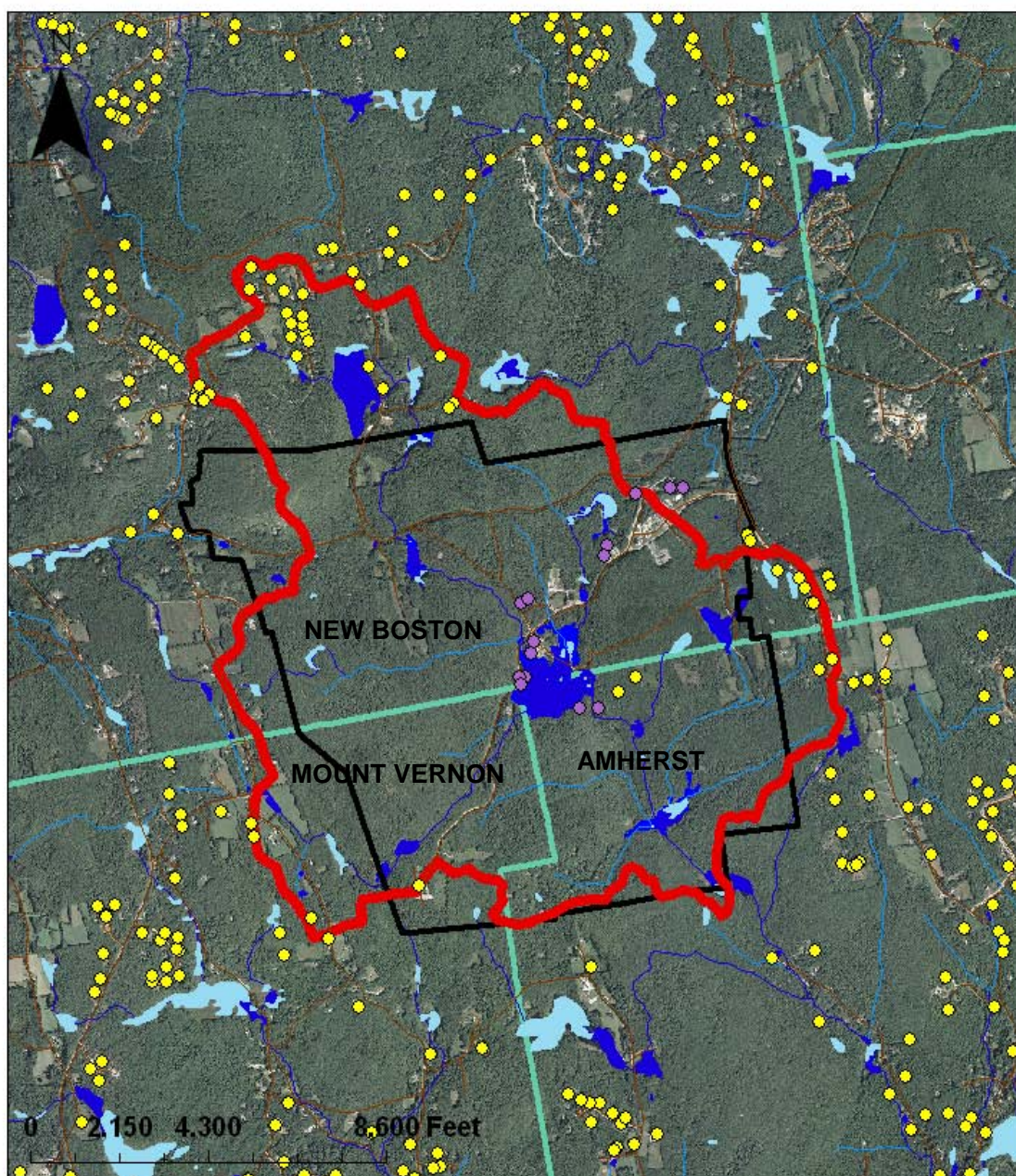


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**Figure 3-5: Groundwater Monitoring Wells Flow Direction: Topographic View  
New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
100 ft Contour Intervals: Shaw Environmental, Inc.





#### Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFS Wells
- Public and Private Wells
- Roads

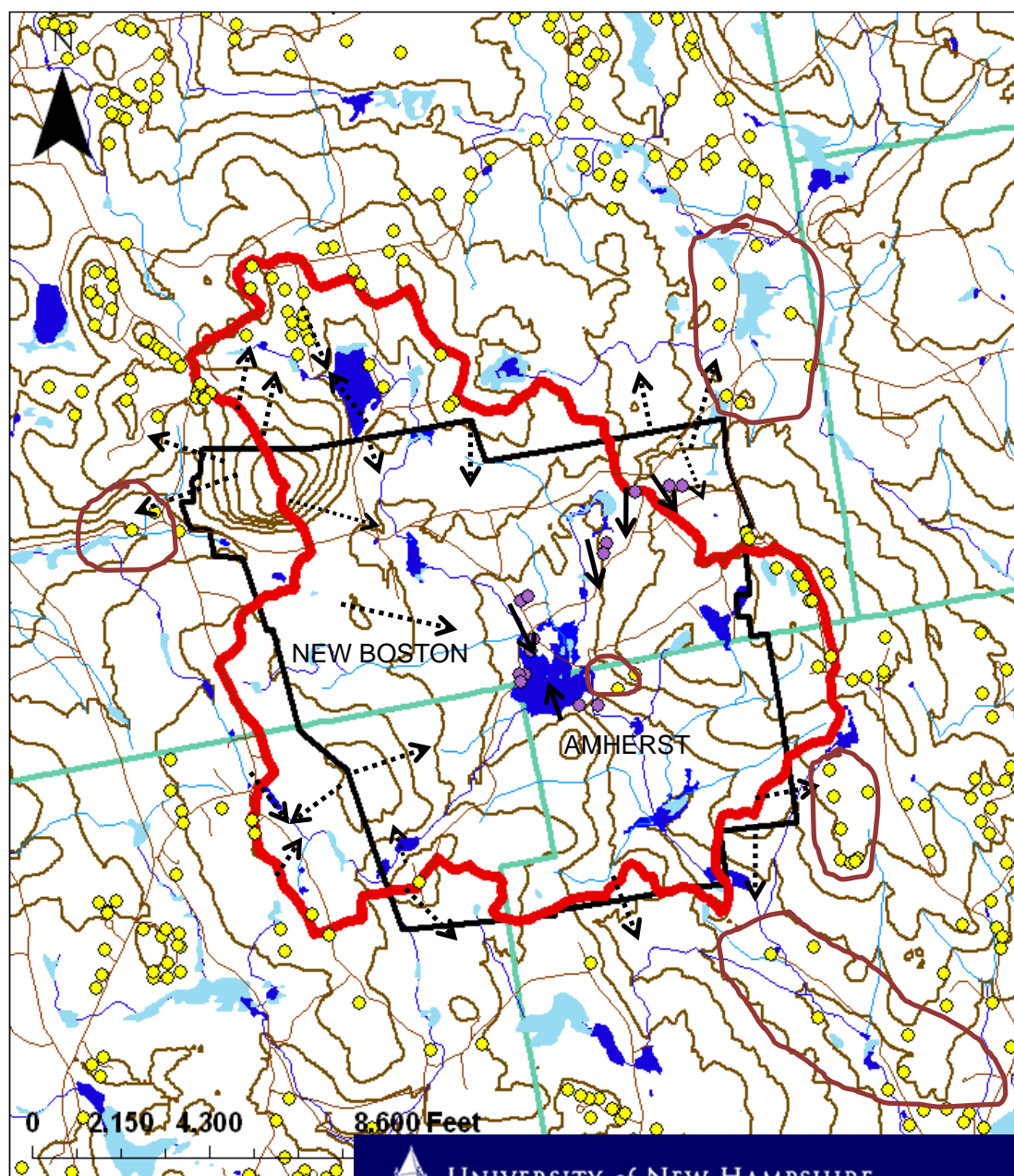
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**Figure 3-6: Location of Public and Private Wells:  
Aerial View  
New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
Aerial Photo: NH Granit



#### Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFS Wells
- Public and Private Wells
- Roads

**1:40,000**



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#### Figure 3-7: Groundwater Flow Direction: Public and Private Wells: Topographic View New Boston Air Force Station

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
100 ft Contour Intervals: Shaw Environmental, Inc.

Estimated Groundwater Flow --> Measured Groundwater Flow -> Wells Potentially Receiving Water from NBAFS ○



**Objective 4:** Identify potential contaminant migration through ground and surface water flow paths using water quality data from Shaw Environmental, Inc.

**Deliverable 4:** Completion of water quality assessment and contaminant migration/transport.

- 1). Written report assessing water quality data obtained by Shaw Environmental, Inc. with respect to identified ground and surface water flow paths.

**Methods:**

Through analysis of the NBAFS Comprehensive Site Evaluation (CSE) Phase II report and NBAFS Site Investigation (SI) report completed by Shaw Environmental, Inc. and received from Jeff Oja on June 16, 2009, an evaluation of the ground and surface water quality on NBAFS was undertaken. Two pieces of this report, entitled “IRP Site Descriptions and Investigation Results” and “Munitions Response Site Characteristics,” provided current groundwater quality data from three wells near JEP (GW3, GW4, and LF001-MW1), and surface water quality data from JEP and JEB, respectively. For the purposes of this study, only water samples from the wells used in this study, as well as those from JEP and JEB were obtained from the report. The regulatory limits of any potential contaminants were then obtained from established EPA Maximum Contaminant Levels (MCLs), EPA Secondary MCLs, EPA Health Advisory Levels, EPA Water and Fish Ingestion Guidelines, and NHDES Ambient Groundwater Quality Standards. Many of the potential contaminants had no published regulatory limit.

Overall, most potential contaminants of concern found in the ground or surface water on NBAFS originated from unexploded ordnance, oil, landfill leachate, and degraded metals from machinery. Human health effects range from short-term nausea and skin irritation, to long term damage to major bodily organs and cancer (EPA, 2009). A list of potential contaminants, their concentrations found in ground and surface water on NBAFS, and established regulatory limits for each potential contaminant are listed in Table 4-1. These standards were used as a benchmark for water quality as nearby residents relying on private wells should be notified if any water originating from NBAFS that enters their wells exceeds regulatory limits so residents can determine if their well is also contaminated and poses health risks.

In previous deliverables, it has been shown that both ground and surface water leave NBAFS through the outlet at JEB as well as through other groundwater flow paths. “Location” in Table 4-1 is arranged along a flow path (Figure 4-1) beginning in the three wells located upslope of the pond (LF001-MW1, GW-3, and GW-4), to JEP and JEB. Water quality data was available from 2006 and 2007.

### **Data Summary:**

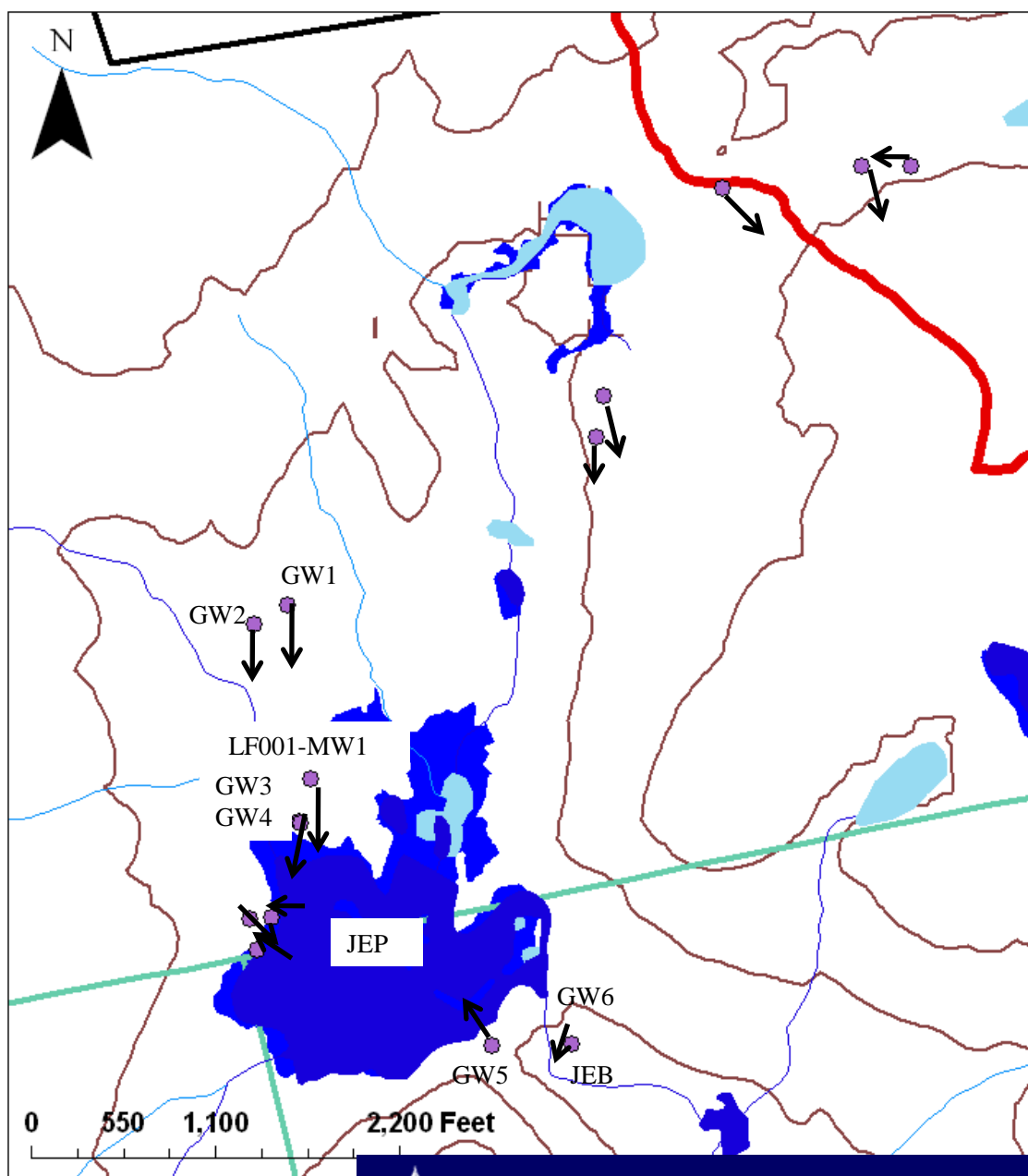
Based on the most recent data available for an individual location (Table 4-1), it can be seen that one contaminant exceeded the established regulatory limits in surface water. For surface water, JEP was analyzed for 11 explosives on 1 date, and of these, 1 exceeded regulatory limits. JEB was analyzed for 11 explosives on 2 dates, and of these, none exceeded regulatory limits. JEP and JEB were analyzed for 11 metals on 2 dates, and of these, 3 exceeded the regulatory limit. For groundwater, six wells were sampled for 21 metals and of these, 2 exceeded regulatory limits. However, as discussed in the CSE Phase II report, these analytes were determined to be attributable to background concentrations. Groundwater was not analyzed for explosive contaminants.

### **Future Sampling Recommendations:**

A background determination for metal concentration in surface and groundwater was carried out by Shaw Environmental, Inc. on conservation lands that border the installation. They found that concentrations of aluminum, chromium, copper, iron, manganese, lead, and mercury were attributable to background. Because one explosive contaminant was found to exceed regulatory limits in surface water, it is recommended that monitoring of this site continue. Further, though many potential contaminants were below detection limits, some detection limits were above a set regulatory limit. As such, it is recommended that future sampling of both ground and surface water for these potential contaminants should be conducted with lower detection limits.

The temporal and spatial variability in water quality may not be accounted for in this study as individual wells or surface water sites were sampled only once. Water quality, particularly surface water quality, can vary with season and during precipitation events which cause a flushing of nearby soils. It is likely that the concentrations of potential contaminants vary both annually and throughout a given year. Further, many of the sampling locations were not analyzed for the same list of potential contaminants (i.e. groundwater was not sampled for explosives). As such, it is possible that not all potential contamination was identified with this current sampling analysis. It is recommended that a more regular and extensive sampling regime of groundwater wells, JEP, and JEB be implemented to account for both spatial and temporal fluctuations in water quality as well as to monitor current locations where concentrations exceed the regulatory limit.

Though this study notes the water quality of water leaving the base through JEB, water was also found to leave the base via groundwater at the northeast, northwest, and southeast corners of NBAFS (Deliverable 3, Figure 3-7). No water quality data is available for these areas, and it is recommended that groundwater in these areas be sampled for potential contamination.



#### Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFS Wells
- 1:10,000**



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**Figure 4-1: Groundwater Monitoring Wells Flow Direction and Water Quality Flowpath:  
Topographic View: New Boston Air Force Station**

NH Water Resources Research Center  
Hydrology and Watershed Analysis NBAFS  
100 ft Contour Intervals: Shaw Environmental, Inc.

**Table 4-1:** Ground and surface water concentrations (µg/L) of potential contaminants on NBAFS

Analyte	Location	LF001-MW1	GW-3	GW-4	JEP	JEB
	Water Type	Ground	Ground	Ground	Surface	Surface
	Regulatory Limit (µg/L)	Results	Results	Results	Results	Results
<b>Explosives (µg/L)</b>						
2,4,6-Trinitrotoluene	NEL				BDL!	BDL!
2,4-Dinitrotoluene	0.11				0.33!	BDL!
2,6-Dinitrotoluene	0.11				BDL!	BDL!
2-Amino-4,6-Dinitrotoluene	0.11				BDL!	BDL!
4-Amino-2,6-Dinitrotoluene	0.11				BDL!	BDL!
Nitrocellulose	NEL				BDL!	BDL!
Nitroglycerin	NEL				BDL!	BDL!
RDX	NEL				BDL!	BDL!
Tetryl	NEL				BDL!	BDL!
Perchlorate	15				BDL!	
<b>Metals (µg/L)</b>						
Aluminum	50	BDL*	BDL*	BDL*	828!	BDL!
Antimony	6	BDL*	BDL*	BDL*	BDL!	BDL!
Arsenic	10	BDL*	BDL*	BDL*		
Barium	2000	BDL*	BDL*	BDL*		
Beryllium	4	BDL*	BDL*	BDL*		
Cadmium	5	BDL*	BDL*	BDL*		
Calcium	NEL	4610*	14100*	11000*	2120!	2100!
Chromium	100	BDL*	BDL*	BDL*	BDL!	BDL!
Copper	1300	BDL*	BDL*	BDL*	BDL!	BDL!
Iron	300	BDL*	BDL*	BDL*	2660!	384!
Lead	Action Limit 15	BDL*	BDL*	BDL*	BDL!	BDL!
Magnesium	NEL	BDL*	BDL*	BDL*	BDL!	BDL!
Manganese	50	15.1*	BDL*	BDL*	206!	69!
Mercury	2	BDL*	BDL*	BDL*	BDL!	BDL!
Potassium	35000	BDL*	BDL*	BDL*		
Selenium	50	BDL*	BDL*	BDL*		
Silver	100	BDL*	BDL*	BDL*		
Sodium	100-250 mg/L	BDL*	16700*	BDL*		
Thallium	2	BDL*	BDL*	BDL*		
Vanadium	NEL	BDL*	BDL*	BDL*		
Zinc	5000	BDL*	BDL*	BDL*	BDL!	BDL!

Sample Dates: October 2006!; August 2007\*

NEL: No established limit

BDL: Below Detection Limits

EPA 2009 Maximum Contaminant Level (national drinking water standards) (EPA, 2009)

EPA 2009 Secondary Maximum Contaminant Level (contamination level that affects aesthetic characteristics of drinking water (EPA, 2009a)

NHDES Ambient Groundwater Quality Standards (Shaw Environmental, Inc. 2009)

EPA Health Advisory Level (EPA, 2009b)

EPA Water and Fish Ingestion Standard (EPA, 2009c)

Exceeds regulatory limit

BDL, however detection limit exceeds regulatory limit

Exceeds regulatory limit, however below background levels





## **Title:** Watershed Assessment of New Boston Air Force Station (NBAFS)

Emily DiFranco and William H. McDowell

University of New Hampshire



### **Study Purpose:**

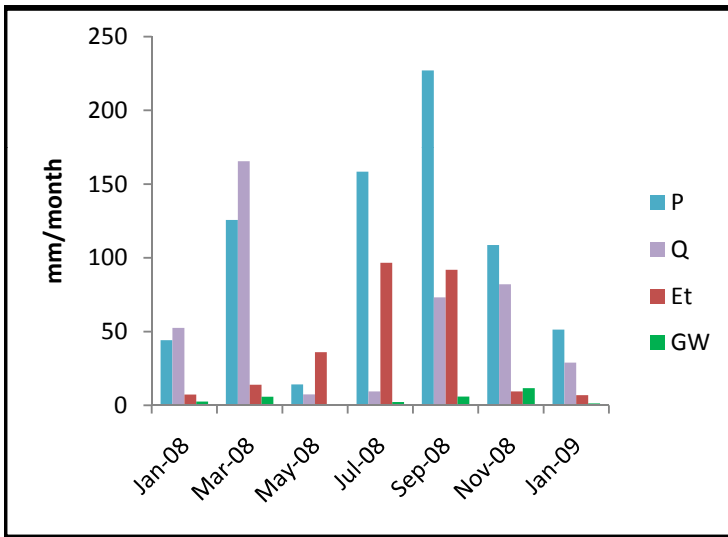
- Assess the quantity and distribution of surface and groundwater resources of NBAFS

### **Research Objectives:**

- Delineate the watershed on NBAFS
- Determine surface and groundwater flow paths within NBAFS
- Create an annual hydrologic budget using the model BROOK 90
- Evaluate current water quality data

### **Hydrologic Budget:**

Figure 1: Annual hydrologic budget for NBAFS

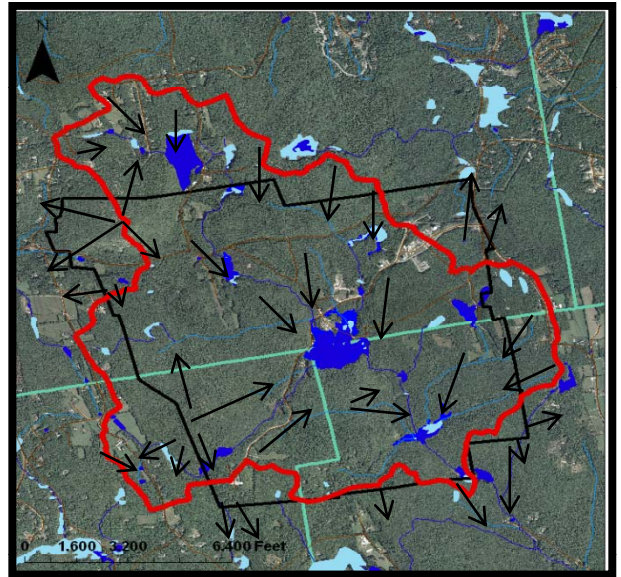


### **Summary of Hydrologic Budget:**

Most water that enters the base as precipitation (P) leaves as discharge (Q) through Joe English Brook. Precipitation was highest in the spring and fall. Highest discharge occurred in March (spring melt). Lowest discharge occurred in the summer months. In general, evapotranspiration (Et) was lowest in the winter months. Groundwater (GW) was lowest in the summer due to lower precipitation and higher demand from plants.

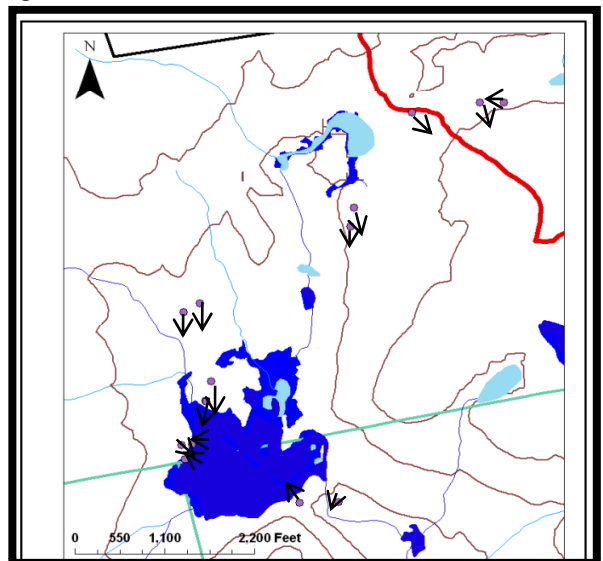
### **Surface Water Flow:**

Figure 2: NBAFS watershed and surface water flow direction



### **Groundwater Flow:**

Figure 3: NBAFS groundwater wells and groundwater flow direction



### **Summary of Surface and Groundwater Flow:**

Most surface and groundwater on the base enters Joe English Pond and leaves the base through Joe English Brook. Sections of the base fall outside of the watershed boundary, indicating water flows off base in these areas.

## **References:**

- Federer, C.A., C. Vörösmarty, and B. Fekete. 2003. Sensitivity of annual evaporation to soil and root properties in two models of contrasting complexity. *J Hydrometeorology* 4:1276-1290.
- Shaw Environmental, Inc., New Boston Air Force Station Preliminary Assessment/Site Investigation Installation Restoration Program: Final Work Plan, May 2007.
- Shaw Environmental, Inc., New Boston Air Force Station CSE Phase II: Received June 16, 2009.
- U.S. Environmental Protection Agency, Drinking Water Contaminants; updated March 18, 2009 <<http://www.epa.gov/safewater/contaminants/index.html>>, accessed April 8, 2009.
- U.S Environmental Protection Agency (a), Secondary Maximum Contaminant Levels; updated November 28, 2006 < <http://www.epa.gov/OGWDW/consumer/2ndstandards.html> >, accessed July 7, 2009.
- U.S. Environmental Protection Agency (b), Drinking Water Contaminants; updated January 13, 2009 < <http://www.epa.gov/ogwdw000/contaminants/unregulated.html> >, accessed July 6, 2009.
- U.S. Environmental Protection Agency (c), National Recommended Water Quality Criteria; updated June 24, 2009 < <http://www.epa.gov/waterscience/criteria/wqctable> >, accessed July 10, 2009.

# Urbanization Impacts on NH Streamwater Thermal Loading

## Basic Information

<b>Title:</b>	Urbanization Impacts on NH Streamwater Thermal Loading
<b>Project Number:</b>	2008NH87B
<b>Start Date:</b>	3/1/2008
<b>End Date:</b>	2/28/2010
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	1st NH
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Surface Water, Non Point Pollution, Water Quality
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Jennifer Jacobs, Thomas P. Ballesterro, Robert Roseen

## Publication

1. Jacobs, J.M., T. Richard, and R. Abele. 2010. Summer Water Temperatures in NH and MA Coldwater Streams. New England Association of Environmental Biologists Conference. March 17-19. Newport, Rhode Island.

# **Annual Report**

## **Urbanization Impacts on NH Streamwater Thermal Loading**

### **PI: J.M. Jacobs**

## **1. Problem**

Research suggests that watershed urbanization may have a significant impact on the thermal regime of the stream that drains the impacted area (Krause et al. 2004, Wheeler et al. 2005). Paul and Meyer (2001) list urbanization as a major cause of impairment in streams and rivers, second only to agriculture. In studies dating from the late 1960's, documented urbanization impacts to stream temperature include increases of 5-6°C (Pluhowski 1968, Pluhowski 1970).

Recent research indicates that impervious areas may increase stream temperature following a rainfall event (Nelson and Palmer 2007, Herb et al. 2008, Thompson et al. 2008). In addition, stream crossings, such as culverts, are also suspected to impact stream water temperature. Though temperature impacts are not yet documented, stream crossings impact the macroinvertebrate community (Khan and Colbo 2008) and the geomorphic properties downstream of the crossing. Both are indicative of a change in the thermal regime of the stream.

## **2. Objectives**

The purpose of this research is to study the impacts on urbanization on small streams as they relate to water temperature, with a particular focus on the effects of stream crossings and impervious surfaces. The overall objective will be met by addressing the following three specific objectives:

*Objective 1:* To develop a database of thermal impacts from storm runoff that includes temperature measurements for typical New Hampshire streams.

*Objective 2:* To determine the timing and magnitude of thermal differences upstream and downstream of storm runoff.

*Objective 3:* To model culvert and impervious area impacts on stream temperature.

## **3. Methods**

The overall approach is to monitor temperature upstream and downstream of the stormwater contributing feature. High resolution profiles of temperature using Fiber Optic Distributed Temperature Sensing (FODTS) and ancillary meteorological and vegetation shading data will be measured during one intensive field campaign (IFC). These data will be used to develop a database of thermal impacts from storm runoff that includes temperature measurements for typical New Hampshire streams (Objective 1).

### **3.1. Continuous Stream Monitoring**

Experimental data necessary to test the hypotheses were collected within multiple study streams, at urbanized reaches within the streams. The target streams include mainly 1<sup>st</sup> and 2<sup>nd</sup> order streams that have a wide range of impacts (Table 1). Each study site has a unique

combination of impervious area, stream crossings, land use, and riparian zone. Study streams all are within close proximity of a road crossing. Impervious area within the study reaches ranges from 3 to 47%.

At the 9 study sites listed in Table 1, hydrologic instruments monitored stream temperature upstream and downstream of potential thermal inputs continuously for at least one year. Several sites have multiple sensors that were used to measure additional downstream locations. To the extent possible, ancillary measurements including stream stage or flow were monitored. Atmospheric conditions were obtained from NOAA's Durham (Kingman Farm) site.

Table 1: Study locations throughout Coastal New Hampshire.

Stream Name	Location	Impervious Area (%)	Road Crossings	Watershed Area (km <sup>2</sup> )	Collection Dates
Berry Brook	Dover, NH	47	4	1.06	2/09-12/09
Chesley Brook	Durham, NH	6	1	3.93	4/09-12/09
College Brook	Durham, NH	30	7	1.83	12/07-12/09
Gerrish Brook	Dover, NH	5	1	4.06	7/08-11/08
Great Brook	Kingston, NH	3	7	6.51	7/08-11/08
Hodgson Brook	Portsmouth, NH	38	8	9.26	7/08-12/09
Lee Five Corners Brook	Lee, NH	9	4	1.32	4/09-12/09
Reservoir Brook	Durham, NH	29	9	1.30	7/09-12/09
Wednesday Hill Brook	Lee, NH	15	1	1.14	10/08-12/09

### 3.2. Stream Thermal Sampling IFC

The 2009 IFC was conducted in Hodgson Brook. Because equipment were available beyond the originally planned one week period, a 50 day FO DTS survey was conducted along with enhanced temperature, water level, and streamflow measurements. During the IFC, a series of temperature measurements were made along the cable with a 1 m spatial, a 1 minute temporal resolution, and a 0.1°C accuracy with 0.01°C resolution. A total of 13 rainfall events were observed during the IFC.

## 4. Major Findings and Significance

Stream temperature data from upstream and downstream of urban areas were compared. Results showed differing upstream and downstream thermal characteristics (**Figure 1**). Baseflow analyses showed that impervious areas were associated with increased daily average temperatures (**Figure 2**). In addition, distinct “temperature surges” were identified during certain rainfall events. Temperature surges were found to occur more often and with greater magnitude in more urban areas, particularly those downstream of road crossings (**Figure 3**). Warm temperature pulses were identified during intense rainfall periods in the Hodgson Brook IFC (**Figure 4**). Overall, the experimental data showed that both culverts and impervious areas influenced stream temperatures during either baseflow or stormflow conditions.

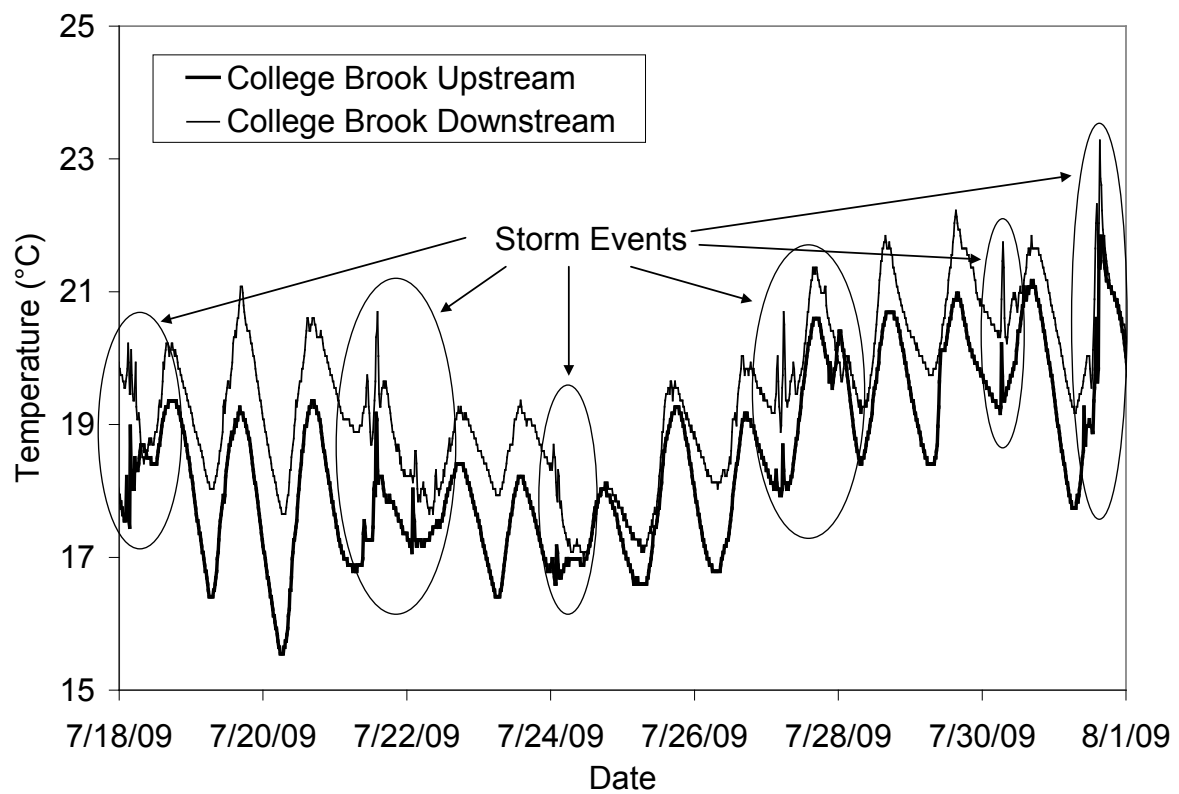


Figure 1: College Brook stream temperature time series.

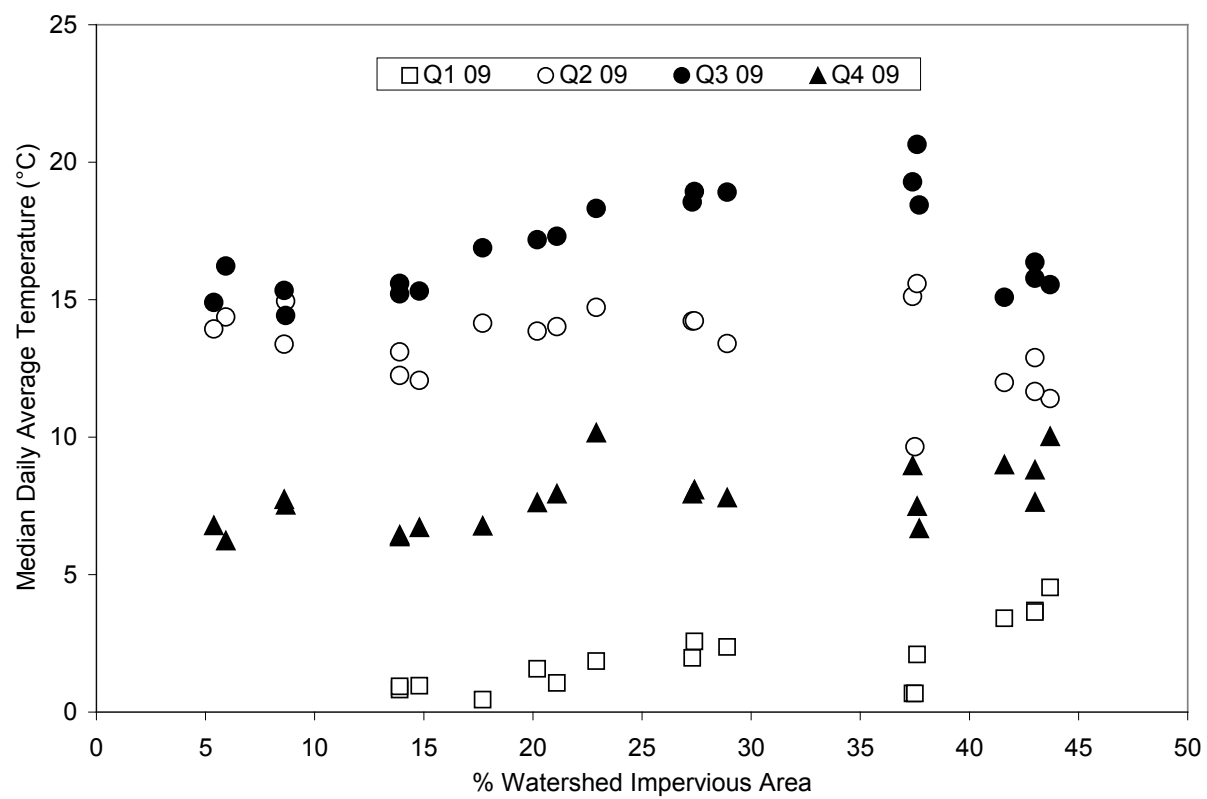


Figure 2: Impervious area versus quarterly median daily average temperature.

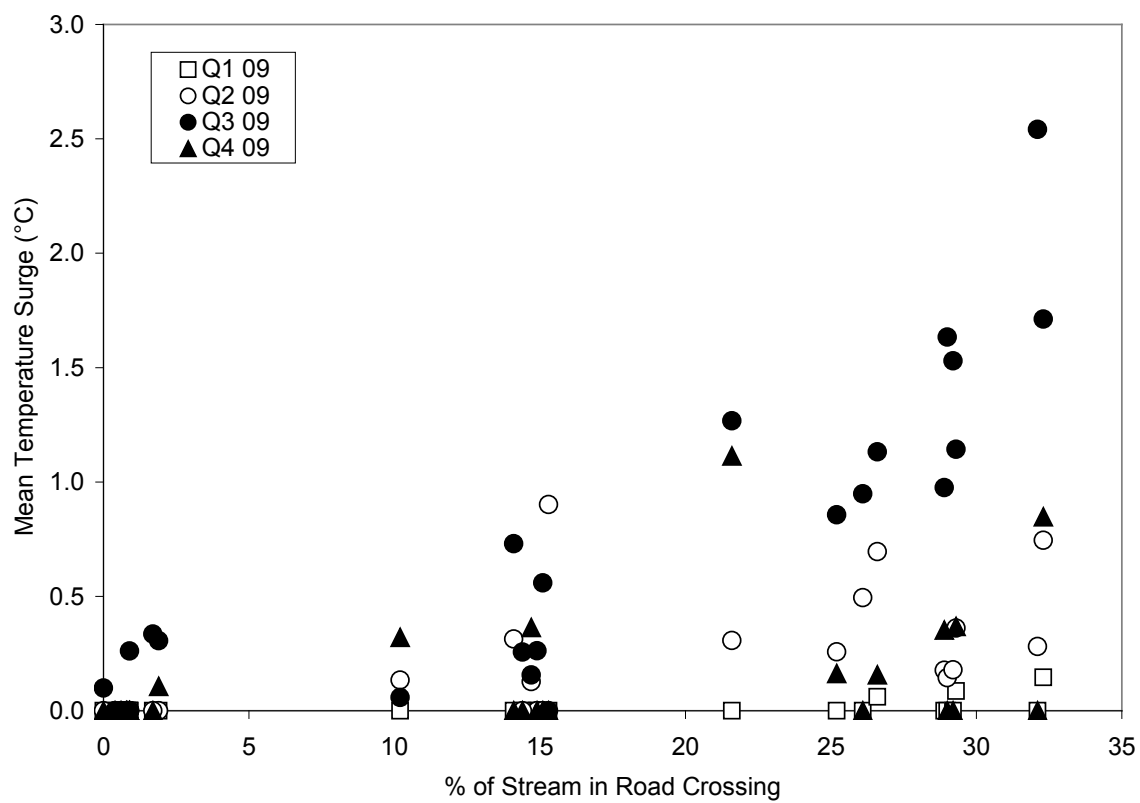


Figure 3: % of stream in a road crossing versus quarterly mean temperature surge.



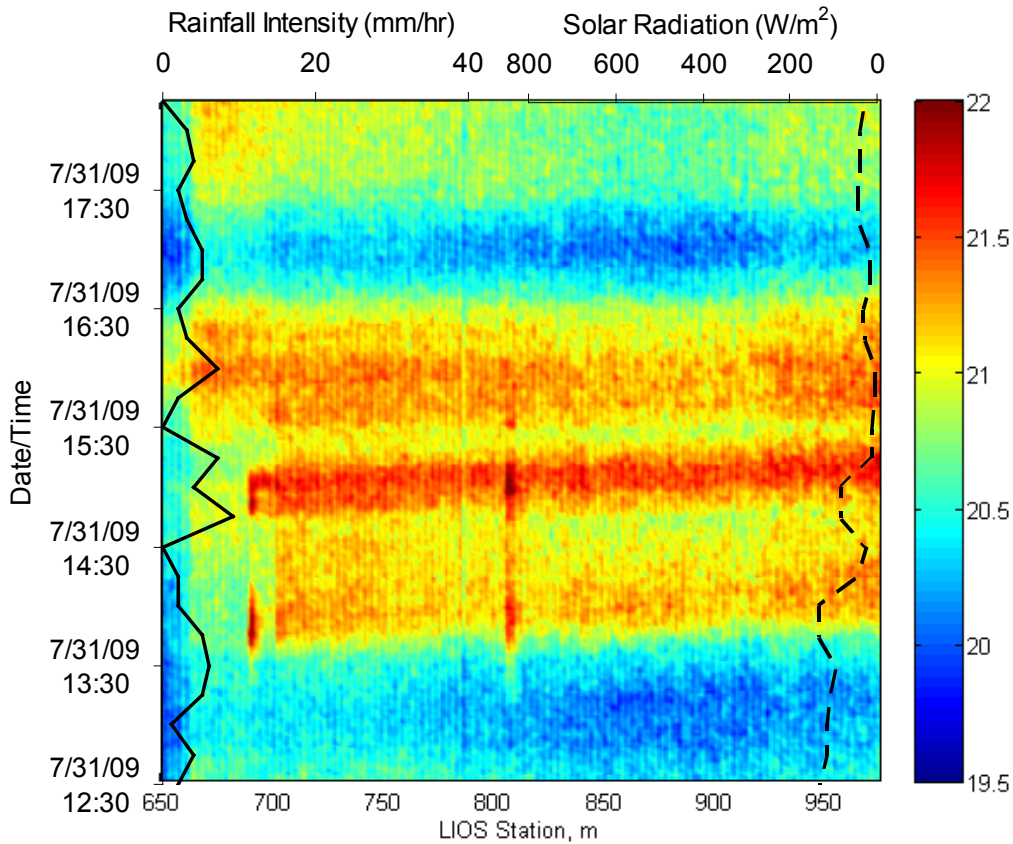


Figure 4: Hodgson Brook spatiotemporal stream temperature plots for storm 5 of 13. Storm drains are located at 680 m FO DTS. Runoff from parking lot located at 810 m FO DTS. Rainfall and solar radiation during the storm are also shown. The color bar corresponds to the stream temperature (°C).

Stream temperatures were modeled for several of the monitored stream reaches. The objective was to determine the primary energy fluxes driving urban stream temperatures. Results showed that solar radiation was generally the largest energy influx, while net longwave radiation and latent heat were the largest energy effluxes. Culverts underneath road crossings substantially changed streams' energy fluxes, often resulting in cooling temperatures inside culverts. In areas with large amounts of impervious area canopy density was often reduced, increasing solar radiation. **Figure 5** shows the average energy fluxes and stream temperatures from 7/15/09 to 8/13/09.

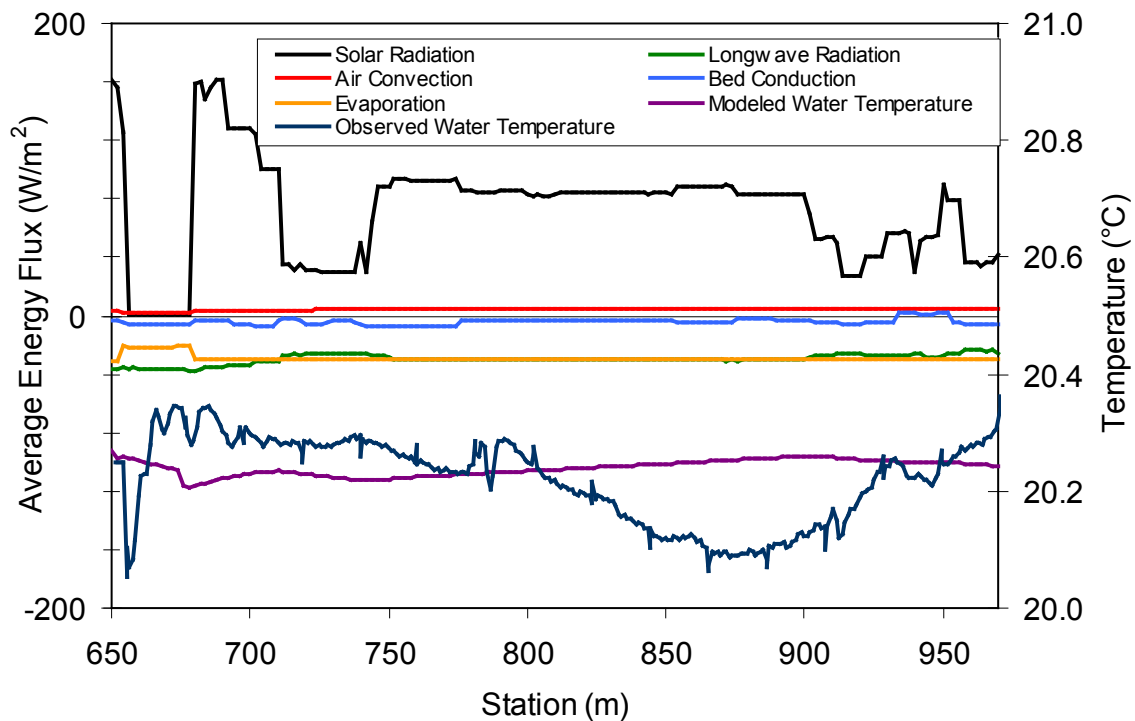


Figure 5: Hodgson Brook longitudinal profile of average energy fluxes and temperatures from 7/15/09 to 8/13/09.

## 5. Publications, Presentations, and Awards

Lemay, G. "Stream Temperature Impacts of Culverts and Impervious Areas" Civil Engineering Alumni Conference. University of New Hampshire. April 30 and May 1, 2010.

Lemay, G. "Stream Temperature Impacts: Lamprey Case Study" Lamprey River Symposium. University of New Hampshire. January 8, 2010.

Jacobs, J.M., T. Richard, and R. Abele. 2010. Summer Water Temperatures in NH and MA Coldwater Streams. New England Association of Environmental Biologists Conference. March 17-19. Newport, Rhode Island.

Lemay, G. and Jacobs, J.M. "Impacts of Culverts and Impervious Areas on Stream Temperature in Coastal NH Streams" North Atlantic Chapter of the Society for Environmental Toxicology and Chemistry Annual Conference. Durham NH. June 10-12, 2009.

Jacobs, J.M. "Stream Temperature What's Hot, What's Not!" Natural Resources Seminar. University of New Hampshire. April 24, 2009. Invited Speaker.

Lemay, G. and Jacobs, J.M. "Impacts of Impervious Areas and Culverts on Stream Temperature" Lamprey River Symposium. University of New Hampshire. January 16, 2009.

Jacobs, J.M. "Lamprey River Tributaries" Lamprey River Symposium. University of New Hampshire. January 16, 2009.

Jacobs, J.M. “Stream Temperature Tricks and Treats”, EPA Regional Science Council. November 5, 2008. Boston, Massachusetts. Invited Speaker.

Jacobs, J.M. “Environmental System Characterization Using Temperature Measurements”, New England Regional Temperature Meeting. July 24, 2008. Turners Falls, Massachusetts. Invited Speaker.

Jacobs, J.M. “Fiber Optics Distributed Temperature Sensing: Technology and Scientific Inquiry” Environmental Research Group Seminar. University of New Hampshire. March 7, 2008. Invited Speaker.

Jacobs, J.M. “Stream Temperature Sensing: Technology and Scientific Inquiry” Department of Civil and Environmental Engineering Seminar. Tufts University. April 15, 2008. Invited Speaker.

## 6. Publications from Previous N/A

## 7. Outreach or Information Transferred

In addition to the presentations during the past year, numerous extension opportunities have occurred. They are briefly summarized below.

Organization	Topic
NH Fish and Game	Collaboration of monitoring efforts and review of NH coldwater fish datasets
MA Fish and Wildlife	Information exchange and development of collaborative agreements
USEPA Region I	Relationship between instream flow, water quality efforts and stream water temperature
Office of Water Resources	Groundwater depletion effects on stream temperature
MA Dept of Conservation and Recreation	
MA Riverways Group	Groundwater depletion effects on stream temperature
Hodgson Brook Watershed Group	Development of collaborative efforts in the watershed. Site potential for FODTS study
UNH Statistical Hydrology Course	Data were used in the PIs’ Statistical Hydrology course in Spring 2009 (12 graduate students)
Hodgson Brook Watershed Group	Development of collaborative efforts in the watershed. Site collaborator for FO DTS study

## 8. Students Supported

This project is partially supporting Gary Lemay, a Masters student in Civil Engineering. He will complete his M.S. degree in June, 2010. Additional students have gained research experience through this project including graduate students Danna Truslow, Nick DiGennaro, Carrie Vuyovich, Ram Ray and undergraduations Logan Kenney (Civil Engineering), Rusty Jones (ESci), and Heidi Borchers (Environmental Engineering). In addition to G. Lemay, graduate students James Sherrard and Carrie Voyuvich participated in the 2009 IFC and were trained in FO DTS best methods. Project participants who are not students include Matt Lavigne and Prof. M. Choi from Hanyang University, Seoul, South Korea.

## 9. References

- Herb, W. R., B. Janke, O. Mohseni, and H. G. Stefan. 2008. Thermal pollution of streams by runoff from paved surfaces. *Hydrological Processes* 22:987-999.
- Khan, B., and M. H. Colbo. 2008. The impact of physical disturbance on stream communities: lessons from road culverts. *Hydrobiologia* 600:229-235.
- Krause, C. W., B. Lockard, T. J. Newcomb, D. Kibler, V. Lohani, and D. J. Orth. 2004. Predicting influences of urban development on thermal habitat in a warm water stream. *Journal of the American Water Resources Association* 40:1645-1658.
- Nelson, K. C., and M. A. Palmer. 2007. Stream temperature surges under urbanization and climate change: data, models, and responses. *Journal of the American Water Resources Association* 43:440-452.
- Paul, M. J., and J. L. Meyer. 2001. Streams in the urban landscape. *Annual Review of Ecology and Systematics* 32:333-365.
- Pluhowski, E. J. 1968. Effects of urban development on the hydrology of Long Island, New York.
- Pluhowski, E. J. editor. 1970. Urbanization and Its Effect on the Temperature of the Streams on Long Island, New York. U.S. Department of the Interior, Washington DC.
- Thompson, A. M., K. Kim, and A. J. Vandermuss. 2008. Thermal characteristics of stormwater runoff from asphalt and sod surfaces. *Journal of the American Water Resources Association* 44:1325-1336.
- Wheeler, A. P., P. L. Angermeier, and A. E. Rosenberger. 2005. Impacts of new highways and subsequent landscape urbanization on stream habitat and biota. *Reviews in Fisheries Science* 13:141-164.

A pilot study of septic impacts on water quality using Boron concentrations and isotopes as a source tracer

## A pilot study of septic impacts on water quality using Boron concentrations and isotopes as a source tracer

### Basic Information

<b>Title:</b>	A pilot study of septic impacts on water quality using Boron concentrations and isotopes as a source tracer
<b>Project Number:</b>	2009NH117B
<b>Start Date:</b>	3/1/2009
<b>End Date:</b>	2/28/2010
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	1
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Groundwater, Non Point Pollution, Methods
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Jeffrey Schloss

### Publications

There are no publications.

**A Pilot Study Of Septic Impacts On Water Quality:  
Using Boron Concentrations And Isotopes As A Source Tracer  
Status Report: March 1, 2009 through February 28, 2010**

Statement of Regional or State Water Problem-

Septic systems are designed to reduce environmental impact from household wastes.

However, when septic densities are too high or when septic systems fail, nutrients and toxic pathogens may be released into groundwater where it can contaminate drinking wells, or may move through the hydrologic cycle to surface water.

Septic systems are not the only source of nutrients and pathogens; natural processes also release them into the ecosystem. Therefore, simply measuring the nutrient concentration in lakes, ponds or rivers is not indicative of septic system pollution. Similarly, pathogens found in human waste are also found in animal waste. For this reason, tracers are often used to map the spatial distribution of septic effluent. The use of tracers to understand the transport and fate of groundwater (including groundwater pollutants), is a common hydrologic practice. Determining concentrations and distribution of concentrations of unique, conservative tracers is a common practice. Stable isotope tracers also have the ability to distinguish between natural and anthropogenic nutrients based on source-unique isotopic ratios or fractionation. For this reason, stable isotope tracers are good tools for assessing the impact of septic systems on ground and surface water. In particular, we are interested in Boron isotopes because of the potential for B (as borate) to serve as a tracer of septic effluent.

Boron has been used in arid environments as a tracer of water sources, but we are not aware of its use in the northeast, and we are not aware of existing borate data from natural waters in the northeast. We hypothesize that borate from septic systems will be higher than natural background. Because we cannot know a priori if total borate will be indicative of septic influence, we are proposing to augment borate data with B isotopes to differentiate human from natural concentrations. If successful, this method will provide a new tool for regulators and environmental groups to monitor water quality and determine sources of contamination

Objectives:

- 1.- To initiate analysis of boron and other possible tracers in water samples collected at septic tanks, test wells and near-shore for a range of septic systems of various ages in a range of suitable and unsuitable soils/slopes.
- 2.-To also conduct sampling that brackets sewage treatment plants as well as sample the outflow from such facilities.
- 3.-To evaluate the use of various tracers for human septage influx that include boron as well as caffeine and a limited number of target compounds that should be commonly used pharmaceutical/personal care products (PPCPs).
- 4- To support graduate student research for a Master's thesis project involving boron and PPCPs.
- 5- The dissemination of the results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.

### Methods:

The septic study was primarily based at the Squam Lakes where we have already conducted an extensive water and nutrient budget study and have compiled a complete GIS analysis system that includes septic system locations and specifications. The Squam Lakes (Squam and Little Squam Lake) benefit from the absence of point sources of pollution like wastewater treatment facilities, industrial facilities or large agricultural operations in close proximity to the shore; however, the role of non-point sources of pollution continues to be an issue. In 2001, Schloss et al. conducted a preliminary survey of septic systems around the Squam Lakes. They found that certain basins were at elevated risk of pollution by septic systems where age of system/design, soil characteristics and slopes were unfavorable to septic waste treatment. This study collected environmental samples from five of the basins found to be at high risk for pollution, one basin at moderate risk, and one basin found to be at low risk of pollution by shore side property septic systems. Shallow water samples were collected using a Van Dorn sampler at 0.5 meters or less. Samples were also collected bracketing 2 sewage treatment plants and at their direct outflow pipe. Samples were analyzed for specific anions/cations, boron, boron isotopes, and, using a modified HPLC/MS procedure: acetaminophen (a common analgesic), caffeine, carbamazepine (an antiepileptic, mood stabilizer) and trimethoprim (an antibiotic) at the NH DES Water Quality laboratory. As part of a companion study funded through the NH WRRC samples were also analyzed for Total Phosphorous in the UNH Center for Freshwater Biology Analytical Laboratory. The emerging contaminants caffeine and triclosan were analyzed through ELISA procedures using very high sensitivity test kits from Abraxis and will be reported upon elsewhere.

### Major Findings and Significance:

As of February 28, 2010 samples were still being processed and analyzed. However, we remain on track for our expected end date of December 2010. A graduate student thesis defense has been set for late May and the Master's Thesis involving the PPCPs and HPLC/MS analytical modifications for those species is currently in review. A manuscript is also being written for submission to a journal such as *Science of the Total Environment*.

Preliminary Boron results indicate that Boron concentrations in control areas are low indicating low natural background concentrations and the possibility of Boron as a tracer for septage.

### Publications, Presentations, Awards:

Forthcoming Masters Thesis in review:

R. Harvey. 2010. Pharmaceuticals and Personal Care Products in the Environment  
Master's Thesis. Plymouth State University Center for the Environment

Manuscript in work:

Occurrence of Acetaminophen, Caffeine, Carbamazepine and Trimethoprim in  
Central NH; a Pilot Study

Outreach:

“Pharmaceuticals and Personal Care Products in the Environment” – a fact sheet by R. Harvey for the Squam lakes Association.

Number of students supported:

Graduate:

Jeff Schloss PhD Natural Resources and Earth Systems Science

Rebecca Harvey MS Environmental Science and Policy Plymouth State University



# **Information Transfer Program Introduction**

None.

## New Hampshire WRRRC Information Transfer

### Basic Information

<b>Title:</b>	New Hampshire WRRRC Information Transfer
<b>Project Number:</b>	2008NH97B
<b>Start Date:</b>	3/1/2008
<b>End Date:</b>	2/28/2011
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Nitrate Contamination, Non Point Pollution, Water Quality
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	William H H. McDowell

### Publications

There are no publications.

## Information Transfer

In New Hampshire, state regulations, planning board decisions and zoning classifications all address the environmental consequences of rapid population growth. Despite the urgency of the problem of unchecked population growth, the decisions by these various resource managers are often made without a real understanding of the consequences to water resources or ecosystem services. This project provided salary for the Center's Director and Associate Director to meet with state representatives, local town officials, watershed groups, the general public and scientists to discuss WRRC findings that relate to population growth. The NH WRRC website (<http://www.wrrc.unh.edu/>) is also used to disseminate information on water resources, and is also updated and maintained by salary provided by this project. The time of the Director and Associate Director is increasingly spent discussing current and future research in the Lamprey River Hydrologic Observatory, which is partially funded by the longstanding 104B project "Water Quality and the Landscape: Long-term monitoring of a rapidly developing suburban watershed." On January 8, 2010 the NH WRRC totally funded and organized the **Third Annual Lamprey River Symposium** (see also below). Presentations focused on water quality, hydrology, stormwater, nitrogen cycling in coastal New Hampshire and also the effects of forest fragmentation and water chemistry on vernal pool-breeding amphibians. The symposium attracted almost 70 attendees, including scientists (33 from UNH and 4 from elsewhere), regional leaders (15), town officials (7), members of state agencies (4), and federal agencies (3). The agenda and presentations have been posted on the NH WRRC website at: <http://www.wrrc.unh.edu/lrho/symposium.htm>. This annual symposium and other discussions in which the Center's Director and Associate Director participate further the research and information transfer goals of the WRRC.

### Examples of Information Transferred

The NH WRRC's long-term water quality data on the rapidly developing suburban Lamprey River watershed has been shared with local towns as they investigate new potential sources for public water supply. Several towns in the watershed are investigating new water supplies to support the increased demand for water from their growing populations. Newmarket, NH is under considerable pressure to develop new water supplies, as its surface water treatment plant was shut down several years ago due to high concentrations of dissolved organic carbon (DOC). This DOC, although of largely natural origin from wetlands in the Lamprey River basin, results in production of dangerous trihalomethanes upon chlorination. Trihalomethanes are known carcinogens and the town of Newmarket was required to shut down the water treatment plant and rely solely on the two town wells.

Newmarket has contracted with Emery & Garrett Groundwater, Inc (EGGI) to increase their town water supply. Emery & Garrett Groundwater, Inc has suggested that the town withdraw water from the Lamprey River in Lee NH during high flow periods and artificially "recharge" their town wells to generate an underground storage supply that would meet the town water needs even during dry summer conditions. The NH WRRC provided EGGI with long-term Lamprey River data to assess whether seasonality and year to year variability in water quality made it appropriate for artificial recharge. The town of Newmarket is still working towards approval of this project, but the long-term dataset provided by the NH WRRC has been instrumental in this water supply decision-making process.

In addition to providing data on surface water quality, the NH WRRC has also identified water quality impairments in private wells within southeastern NH and presented the results to homeowners and local town officials. Private wells are not regulated, even though they supply 40% of the NH population, and therefore it is up to the individual homeowner to test and treat their water if necessary. This puts the uninformed homeowner at risk of consuming contaminated water. We sampled 188 private wells to infer linkages between land use practices and groundwater quality and to educate the general public on the importance of private well testing. One well exceeded the US EPA public drinking water standard for nitrate (10 mg N/L), 10 wells were greater than levels associated with increased risk of gastric cancer (4 mg N/L; Ward et al. 1996), and 28 wells were elevated above 2 mg N/L, indicating anthropogenic sources of N contamination (e.g. fertilizers or septic system effluent). Nine percent of the wells exceeded the EPA secondary drinking water standard for chloride (250 mg/L) and 46% of the wells exceeded the EPA advisory level (20 mg Na/L) for persons with hypertension. It is likely that road salt application is the dominant source of such high sodium and chloride levels in groundwater. In summary, 21% of the wells exceeded the EPA MCL for either nitrate, arsenic, lead or uranium and 38% of the wells exceeded advisory levels for nitrate (4.0 mg N/L), chloride (250 mg/L) or sodium (20 mg/L). A total of 59% of private well users are exposed to contaminants that are cause for health concern. The NH WRRC has shown that even private wells drilled deep into bedrock fractures are subject to contamination from activities on the land surface. These results were included within many of the presentations listed below.

Over the past year, there has been significant focus on nitrogen loading to New Hampshire's largest estuary, the Great Bay estuary, and the impairment to aquatic life it has caused. In June 2009, numeric nitrogen criteria were established for Great Bay and in August 2009, Great Bay, Little Bay and the tidal rivers were added to the New Hampshire 2008 303d list of impaired waters rendering them in violation of the federal Clean Water Act. Based on a draft version of a waste load allocation report prepared by Philip Trowbridge (NH DES), only 22% of the nitrogen entering Great Bay and Little Bay is from point sources; the majority (78%) enters via non-point sources of pollution. The Lamprey River is the largest tributary to Great Bay, and thus the data provided by the NH WRRC from the LRHO are of considerable value for watershed management. The WRRC data focus on the spatial and temporal variability in N concentrations and export throughout the watershed over the last 10 years. There is much interest in LRHO datasets from NH DES, the Piscataqua Region Estuaries Partnership (PREP), the Environmental Protection Agency (EPA) and other municipal, regional, state and federal agents. Many of the presentations and meetings listed below focused on transferring information on nitrogen cycling to stakeholders throughout NH's coastal watershed and beyond.

### **Presentations:**

Daley, M.L. 2009. Current Water Quality Research in the Lamprey River Watershed. Southern New Hampshire Planning Commission Meeting. Manchester, NH. April 2009.

Daley, M.L. 2009. Current Water Quality Research in the Lamprey River Watershed. Rockingham Planning Commission and Strafford Regional Planning Commission special joint meeting. Exeter, NH. May 2009.

- Daley, M.L. 2009. Water Quality Research in the Lamprey River Watershed: Road Salt and Nitrogen. Lamprey River Outreach Conference: "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes Sense For Protecting Our Water". Nottingham, NH. June 2009.
- Daley, M.L. 2009. Current water quality research in the Lamprey River watershed. Lamprey River Advisory Committee. Durham, NH. October 2009.
- Daley, M.L. 2009. Nitrogen Sources and Retention within the Lamprey River Watershed and Implications for Management. State of the Estuaries Conference. Somersworth, NH. October 2009.
- Daley, M.L. 2009. Salt Research, Impacts to Surface & Ground Water. Road Salt BMPs for the Ossipee Watershed. Chocorua, NH. November 2009.
- Daley, M.L. 2009. Water Quality of Private Wells in Suburban NH and Impacts of Land Use. Northeast Private Well Symposium. Portland, ME. November, 2009.
- Daley, M.L. 2009. Spatial and Temporal variability in nitrogen concentrations, export and retention in the Lamprey River watershed. Joint NH Water and Watershed Conference. Concord, NH. November, 2009.
- Daley, M.L. and W.H. McDowell. 2009. Nitrogen Saturation in Highly Retentive Watersheds? American Geophysical Union Fall Conference, San Francisco, CA. December, 2009.
- Daley, M.L. 2010. Nitrogen Saturation in the Highly Retentive Lamprey River Watershed? Annual Lamprey River Science Symposium. Durham, NH. January 2010.
- Dunlap, K. 2010. Seasonal Nitrate Dynamics in a New Hampshire Agricultural Stream. Annual Lamprey River Science Symposium. Durham, NH. January 2010.
- McDowell, W.H. 2009. Biogeochemistry of Suburban Basins – Putting People into the Landscape. University of Georgia. Athens, GA. October, 2009.
- McDowell, W.H. 2009. Biogeochemistry of Suburban Basins – Putting People into the Landscape. University of Reading, United Kingdom. November, 2009.
- McDowell, W.H. 2010. Overview of the Lamprey River Hydrologic Observatory Objectives. Annual Lamprey River Science Symposium. Durham, NH. January 2010.

#### **Meetings Attended:**

- Daley, M.L. 2009. Meet with Lee Water Resources Committee to discuss Lee Water Resource Management Plan. April 2009.

McDowell, W.H. Meeting with NH DES Commissioner Tom Burack and the director of the NH DES Water Bureau Harry Stewart to discuss nitrogen cycling and other water resource issues in NH. Spring 2009.

McDowell, W.H. and Daley, M.L. met with Paul Currier (NH DES), Phil Trowbridge (NH DES), Gregg Comstock (NH DES) and Jim Latimer (EPA) to discuss nitrogen cycling as it relates to N impairments in Great Bay. July 2009.

McDowell, W.H. and Daley, M.L. met with Paul Currier (NH DES) and Phil Trowbridge (NH DES) to discuss nitrogen cycling as it relates to N impairments in Great Bay. October 2009.

Daley, M.L. 2010. Attended NH Water Quality Standards Committee Meeting in Concord, NH. January 2010.

### **Symposia Organized and Funded:**

The NH WRRC totally funded and organized the "**Third Annual Lamprey River Symposium**" held January 8, 2010 in Durham, NH. The symposium is dedicated to exchanging the results of recent research on the water quality, hydrology, water resources issues, and management of the Lamprey River basin. The Symposium is a vehicle for researchers to share data and insights with other researchers, as well as those in the management and policy arena who would benefit from exposure to the latest research on the watershed. The symposium drew almost 70 attendees, including researchers, legislators, water system operators, town officials, regional leaders and government officials. The symposium contained 15 presentations split up over three sessions. There was a poster session during lunch and 3 posters and displays were exhibited. The day ended with an open discussion on research priorities in the watershed and southeast NH. This event was totally funded, organized and moderated by the NH WRRC.

The NH WRRC together with the Great Bay National Estuarine Research Reserve (GBNERR) Coastal Training Program, Lamprey River Watershed Association (LRWA), Lamprey River Advisory Committee (LRAC) and Piscataqua Region Estuaries Partnership (PREP) formed the Lamprey River Watershed Outreach Collaborative and co-sponsored an outreach conference in June 2009 focusing on pressing water issues for the residents of the 14 towns that make up the watershed. The conference was titled "**Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes Sense For Protecting Our Water**". The conference was held in Nottingham, NH on Saturday June 13, 2009 and drew over 70 people including teachers, legislators, town officials, regional leaders and government officials.

In 2009, the organizing committees of the annual New Hampshire Water Conference and the annual New Hampshire Watershed Conference joined forces to offer a single, comprehensive event: the "**Joint NH Water and Watershed Conference**" in Concord, NH on November 20-21, 2009. The merger combined the talent, resources, and audiences from both events into a unique, two-day event designed to meet the information and networking needs of lake, river, and watershed groups; environmental organizations; volunteer monitors; municipal board and staff members; elected officials; local and regional planners; policy makers; scientists; educators; consultants and students. This conference provided a state-wide forum for learning and

networking about issues related to water resources in New Hampshire and drew over 200 people, including researchers, legislators, water system operators, land use planners, and government officials. The NH WRRC co-Sponsored this conference along with the New Hampshire Rivers Council, NH Dept of Environmental Services, NH Lakes, Comprehensive Environmental Inc., Public Service of New Hampshire, Weston & Sampson, Vanasse Hangen Brustlin, Inc., YSI, New England Interstate Water Pollution Control Commission, Naturesource Communications, Gomez and Sullivan and GeoInsight. The conference contained 6 tracks each day including stormwater, climate change, water infrastructure, organizational development, watershed management, land use/ land conservation and a GIS track that was facilitated solely by the UNH cooperative extension and the NH WRRC.

In January 2010, planning began for the “**Road Less Salted**” water quality and salt reduction seminar which was held on May 13, 2010 as a follow-up activity to the conference "Your Water, Your Wallet, Your Watershed - Why Working Together Across Town Boundaries Makes \$ense For Protecting Our Water". The event was co-sponsored by NH Department of Environmental Services, GBNERR Coastal Training Program, LRAC, LRWA, NH WRRC, and Hodgson Brook Restoration Project. Targeted audiences for the seminar were: local boards and commissions, public works directors and road agents, municipal decision makers/planners, private contractors and landscapers who plow snow, property managers or owners, and local watershed or environmental organizations.

# **USGS Summer Intern Program**

None.



<b>Student Support</b>					
<b>Category</b>	<b>Section 104 Base Grant</b>	<b>Section 104 NCGP Award</b>	<b>NIWR-USGS Internship</b>	<b>Supplemental Awards</b>	<b>Total</b>
<b>Undergraduate</b>	13	0	0	1	14
<b>Masters</b>	12	0	0	2	14
<b>Ph.D.</b>	1	0	0	0	1
<b>Post-Doc.</b>	0	0	0	0	0
<b>Total</b>	26	0	0	3	29

## Notable Awards and Achievements

Jeff Merriam, former WQAL manager, received the Distinguished Alumni award from the Department of Natural Resources & the Environment at the University of New Hampshire, Durham, NH. May 2009.

William H. McDowell, WRRRC Director, was invited to speak at the University of Georgia (October 2009) and University of Reading, UK (November 2009), on "Biogeochemistry of a Suburban Basin: Putting People into the Landscape", a presentation based on WRRRC research.

Jeffrey Schloss, PI for research project "Water Quality Change-Effects of Development in Selected Watersheds", was invited to speak at several state, national and international meetings on lake and riparian management. Please refer to the project report contained within this document for a list of presentations.

Jennifer Jacobs, PI for research project "Urbanization Impacts on NH Streamwater Thermal Loading", was invited to give several seminars and speak at various meetings. Please refer to the project report contained within this document for a list of presentations.

## **Publications from Prior Years**

1. 2005NH36B ("Assessing Household Risk and Knowledge in Mitigating Nonpoint Source Pollution in Coastal Watersheds") - Dissertations - Robertson, Mary A. 2010. Social Science and Social Capital in the Lamprey River Watershed: a Resident Survey for Community and Environmental Planning and Predicting Support for Innovative Land Use. Ph.D. Dissertation. University of New Hampshire, Durham, NH. 215 pages.